Important Warning

This document is one of a set of standards developed solely and specifically for use on the rail network owned or managed by the NSW Government and its agencies. It is not suitable for any other purpose. You must not use or adapt it or rely upon it in any way unless you are authorised in writing to do so by a relevant NSW Government agency.

If this document forms part of a contract with, or is a condition of approval by, a NSW Government agency, use of the document is subject to the terms of the contract or approval.

This document may not be current. Current standards are available for download from the Asset Standards Authority website at www.asa.transport.nsw.gov.au.

© State of NSW through Transport for NSW
Standard governance

Owner: Lead Electrical Engineer, Asset Standards Authority
Authoriser: Chief Engineer Rail, Asset Standards Authority
Approver: Director, Asset Standards Authority on behalf of ASA Configuration Control Board

Document history

<table>
<thead>
<tr>
<th>Version</th>
<th>Summary of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>First issue</td>
</tr>
</tbody>
</table>

For queries regarding this document, please email the ASA at standards@asa.transport.nsw.gov.au or visit www.asa.transport.nsw.gov.au

© State of NSW through Transport for NSW
Preface

The Asset Standards Authority (ASA) is an independent unit within Transport for NSW (TfNSW) and is the network design and standards authority for defined NSW transport assets.

The ASA is responsible for developing engineering governance frameworks to support industry delivery in the assurance of design, safety, integrity, construction, and commissioning of transport assets for the whole asset life cycle. In order to achieve this, the ASA effectively discharges obligations as the authority for various technical, process, and planning matters across the asset life cycle.

The ASA collaborates with industry using stakeholder engagement activities to assist in achieving its mission. These activities help align the ASA to broader government expectations of making it clearer, simpler, and more attractive to do business within the NSW transport industry, allowing the supply chain to deliver safe, efficient, and competent transport services.

The ASA develops, maintains, controls, and publishes a suite of standards and other documentation for transport assets of TfNSW. Further, the ASA ensures that these standards are performance based to create opportunities for innovation and improve access to a broader competitive supply chain.

This document has been developed by the Chief Engineer Rail section of the Asset Standards Authority, reviewed by a committee of TfNSW cluster representatives, and approved by the Asset Standards Authority Configuration Control Board.

This standard provides the testing requirements for electrical equipment and associated systems installed in RailCorp substations and 1500 V sectioning huts.

This standard has been updated from RailCorp document EP 99 00 00 02 SP System Substation Commissioning Tests (V3.1). This RailCorp document is withdrawn with the publication of this standard.

This standard is a first issue.
# Table of contents

1. Introduction ........................................................................................................................................ 6
2. Purpose .............................................................................................................................................. 6
2.1. Scope ............................................................................................................................................... 6
2.2. Application ...................................................................................................................................... 6
3. Reference documents ......................................................................................................................... 7
4. Terms and definitions ......................................................................................................................... 8
5. System safety ..................................................................................................................................... 9
6. Testing requirements and project life cycle responsibilities ............................................................... 10
6.1. Designer responsibilities .................................................................................................................. 10
6.2. Commissioning engineer responsibilities ....................................................................................... 10
7. Commissioning - staging document requirements .............................................................................. 11
7.1. Staging diagram requirements ........................................................................................................ 11
7.2. Commissioning plan ....................................................................................................................... 11
7.3. Approval and publication of staging diagrams ............................................................................... 12
8. Recording of ITPs, test methods and results ....................................................................................... 12
9. Pre-commissioning mandatory requirements ..................................................................................... 13
9.1. Building and associated requirements ............................................................................................. 13
9.2. Energisation of HV and 1500 V equipment ..................................................................................... 14
10. Test equipment .................................................................................................................................. 14
11. Equipment tests ............................................................................................................................... 15
11.1. 1500 V dc equipment ....................................................................................................................... 15
11.2. DC auxiliary supply equipment ...................................................................................................... 16
11.3. HV equipment ................................................................................................................................ 16
11.4. HV and 1500 V dc cables ................................................................................................................ 17
11.5. Rail-earth contactor ........................................................................................................................ 17
11.6. Low voltage light and power circuits ............................................................................................... 17
11.7. Emergency lighting (240 V ac) ........................................................................................................ 18
11.8. Automatic auxiliary changeover .................................................................................................... 18
11.9. Auxiliary transformer ..................................................................................................................... 18
11.10. Signalling supply polarity .............................................................................................................. 18
12. System tests ..................................................................................................................................... 18
12.1. Earthing system ............................................................................................................................. 19
12.2. SCADA system ............................................................................................................................. 20
12.3. Rectifier transformer, rectifier, HV ACCB and 1500 V DCCB as a system ................................. 21
12.4. 1500 V feeder DCCB intertrip scheme .......................................................................................... 21
12.5. High voltage supplies ..................................................................................................................... 22
12.6. High voltage indoor switchboards ................................................................................................. 22
12.7. High voltage protection schemes .................................................................................................. 22
12.8. Fire protection system ................................................................................................................... 23
12.9. Lighting system .............................................................................................................................. 24
12.10. Security and substation access .................................................................................................... 24
12.11. Drainage pumps .......................................................................................................................... 24
12.12. Ventilation systems ...................................................................................................................... 25
12.13. Electromagnetic compatibility (EMC) .......................................................................................... 25
12.14. Energy metering (bulk supply point interfaces) .......................................................................... 25
12.15. HV harmonic filter system .......................................................................................................... 25

© State of NSW through Transport for NSW
12.16. Communication system ................................................................. 26

Appendix A - Insulation resistance values ................................................. 27

Appendix B - Electrical continuity test values ............................................. 28

Appendix C - ITP and checklist documentation requirements ...................... 29
1. Introduction

The RailCorp high voltage distribution network has a variety of electrical installations that vary from simple locations with minimal equipment to locations such as traction substations that incorporate both high voltage and 1500 V dc equipment.

Electrical equipment and associated systems in these locations shall be tested to ensure correct operation, functionality and verify that the equipment is safe to energise and operate.

2. Purpose

The purpose of this standard is to detail the testing requirements for electrical equipment and associated systems installed in RailCorp substations and 1500 V sectioning huts.

This enables the development of appropriate commissioning plans and detailed equipment test procedures to ensure that equipment can be connected and integrated into the RailCorp electrical network.

2.1. Scope

This publication sets out the general requirements for the staging and commissioning documentation, type of tests and the recording of test results for individual equipment and associated systems in RailCorp substations and 1500 V sectioning huts.

This publication does not detail the actual testing methods. It requires that the commissioning engineer in conjunction with the designer determines the necessary tests and acceptable results.

2.2. Application

This standard applies to RailCorp substations, 1500 V sectioning huts and the commissioning of the following:

- existing items of equipment following maintenance, overhaul or repair
- new items of equipment installed in an existing system substation
- new substations
- new 1500 V sectioning huts
3. **Reference documents**

**International standards**

EN50121-2:2006 Railway applications – Electromagnetic Compatibility – Part 2: Emission of the whole railway system to the outside world

EN50121-5:2006 Railway applications - Electromagnetic Compatibility - Part 5: Emission and immunity of fixed power supply installations and apparatus

**Australian standards**

AS/NZS 2293.2:1995 Emergency Lighting Testing & Inspection

AS/NZS 3000:2007 Wiring Rules

AS/NZS 3017:2007 Electrical Installations – Verification guidelines

**Transport for NSW standards**

EP 03 02 00 01 SP Controls and Protection for Rectification Equipment

EP 11 00 00 07 SP Design Technical reviews for Electrical SCADA Equipment

EP 19 00 00 03 SP Commissioning of Translay Pilot Wire Protection Scheme

EP 20 00 00 20 SP Testing of High Voltage and 1500 V DC Cables

EP 99 00 00 01 SP Substation Minimum Construction Standards

EP 99 00 00 04 SP Substations - Base Safety and Operating Standard

T HR EL 90001 PR Polarity of AC Signalling Supplies

Technical Note TN 003-2013 Change Authorisation Process for Proposed Operating Diagrams

TS 10507 AEO Guide to Systems Integration

TS 10504 AEO Guide to Engineering Management

TS 10502 AEO Authorisation Requirements

TS 10506 AEO Guide to Verification and Validation

TS 20001 System Safety Standard for New or Altered Assets

**Other reference documents**

Electrical Network Safety Rules (ENSR)

SMS-11-GD-0244 Personnel certifications – Electrical authorisations

National Electricity Rules
4. **Terms and definitions**

The following terms and definitions apply in this document:

**ACCB** alternating current circuit breaker

**AEMO** Australian Energy Market Operator Limited

**authorised personnel** a person who is specifically authorised to perform electrical work on, near and in the vicinity of equipment that forms part of the RailCorp Electrical Network (in accordance with SMS-11-GD-0244)

**commissioning engineer** person or persons deemed competent by the Authorised Engineering Organisation (AEO) who is responsible for the commissioning of the substation equipment and systems

**DCCB** direct current circuit breaker

**design engineer** the person or persons deemed competent by the Authorised Engineering Organisation (AEO) who is responsible for the design

**EMC** electromagnetic compatibility

**enterprise asset management system** systems used by the operator and maintainer to manage the RailCorp assets

Currently the systems used by operator and maintainer include Ellipse, Discrete Asset Data (DAD) and Teams 3.

**IRCS** isolating and rail connecting switch

**ITP** inspection and test plan

**LNSP Local Network Service provider** as defined by the NER, within a local area, a network service provider to which that geographical area has been allocated by the authority responsible for administering the jurisdictional electricity legislation in the relevant participating jurisdiction

**metering provider** a person who has been accredited by and registered by AEMO as a metering provider

**protection engineer** the person or persons deemed competent by the Authorised Engineering Organisation (AEO) and in accordance with the RailCorp distribution network requirements that is responsible for the commissioning and verification of the protection equipment and schemes

**REC** rail earth contactor

**RMU** ring main unit (nominally 11 kV)

**RTU** remote terminal unit

**SCADA** supervisory controlled and data acquisition system
sectioning hut a location which contains 1500 V dc circuit breakers and associated links. There are no high voltage equipment or 1500 V rectifiers

substation following are locations within the RailCorp distribution network which are classified as substations for the purpose of this document:

- any location that includes a high voltage circuit breaker or high voltage fuse
- traction substation
- high voltage switching station
- high voltage switch room
- 2 kV locations
- 11 kV ring main unit locations
- pole top substations

RailCorp distribution network Refer to T HR EL 0001 TI RailCorp Electrical System General Description

UGOH underground to overhead

5. **System safety**

The commissioning and testing of electrical equipment and associated systems is an activity that has inherent hazard and safety risks. These risks are categorised into four areas:

- safety risks to the public or personnel due to transfer of hazards due to the interface with other systems
- operational risks that may affect the integrity or operation of the rail network
- safety risks to personnel conducting the testing and commissioning
- safety risks to personnel not directly involved with the testing and commissioning but present at the location or in the vicinity

Specific risks should be identified for the commissioning and testing activities and comply with TS 20001 Safety System Standard for New or Altered Assets. This standard sets out the requirements for system safety engineering and assurance activities to be conducted in support of the introduction of new or altered assets on the rail network.

All testing and commissioning activities that involve working on or near RailCorp assets shall be planned and managed to ensure compliance with the Electrical Network Safety Rules (ENSR).
6. Testing requirements and project life cycle responsibilities

The commissioning tests prescribed in this document form part of the requirements as detailed in the systems engineering system life cycle model (V model) provided in TS 10504 AEO Guide to Engineering Management and TS 10506 AEO Guide to Verification and Validation.

One of the requirements of the model is to verify the following:

- unit (unit level tests)
- subsystem (subsystem integration level and tests)
- system interfaces (system integration level and tests)
- system (operational system acceptance tests)

TS 10506 AEO Guide to Verification and Validation document provides more details on the general AEO requirements.

6.1. Designer responsibilities

Design verification is required at each level and the designer at the design phase is required to specify the inspection and test plan (ITP) requirements including accept or reject criteria.

During the construction or installation phase the designer shall verify the installation has been installed according to the approved design.

During the inspection and test and commissioning phases the designer shall verify the installation has been tested to meet the design requirements as specified in the ITPs.

6.2. Commissioning engineer responsibilities

The commissioning engineer is required to complete the unit, subsystem and integration tests as part of the inspection and test and commissioning phases.

The inspection and test and commissioning phases shall not commence until the designer has verified the installation.

The commissioning engineer shall develop the ITPs and checklists in accordance with the designer's requirements. The designer shall endorse the final set.

Certain test results may be required by the designer to validate the original modelling that was used to specify the design. One example of this is the earthing system.
7. Commissioning - staging document requirements

A detailed project commissioning plan shall be developed which identifies all the activities, tasks, interfaces, responsibilities, dependencies and associated risk requirements of the commissioning.

Where the commissioning involves more than one stage then documentation consisting of relevant HV ac operating diagrams, dc operating diagrams, HV reticulation diagrams, 1500 V sectioning diagrams and HV system diagrams shall be submitted and approved prior to the commissioning. The diagrams are required for each stage of the commissioning.

TN 003-2013 Change Authorisation Process for Proposed Operating Diagrams details the positions and their responsibilities that are required signatories on the diagrams.

An accompanying commissioning plan which aligns with each stage of the commissioning shall be submitted with the staging diagrams. This documentation shall be version controlled.

7.1. Staging diagram requirements

The staging diagrams shall be presented in a format suitable to be used directly for the preparation of electrical operating diagram advice of alteration. In particular the following should be consistent with the operator and maintainer standards:

- amount of detail consistent with similar diagrams
- equipment symbols and naming conventions
- layout and general conventions
- line styles and colours
- clouding to identify the changes at each stage
- title block in accordance with the RailCorp CAD manual
- drawings registered with RailCorp planroom

The final stage of the diagrams shall reflect the approved proposed operating diagrams.

All location names, HV feeder and 1500 V sectioning identification shall reflect the previously approved proposed operating diagrams.

7.2. Commissioning plan

An accompanying commissioning plan which aligns with each stage of the commissioning and details of the following for each stage is required:

- description of the purpose of this stage
- detail on the main activities to achieve the purpose of the stage
7.3. Approval and publication of staging diagrams

The staging diagrams and commissioning plan shall be approved in accordance with TN 003-2013.

8. Recording of ITPs, test methods and results

A copy of all designer verified ITPs, test methods, test results and calibration reports and certificates shall be recorded and maintained in the operator and maintainer’s enterprise asset management system against the discrete equipment for individual equipment tests and against the location for system tests. The project AEO is required to coordinate with the operator and maintainer to establish the process and ensure the information is recorded.

Where the commissioning is completed in one stage the documentation shall be recorded within four weeks of the commissioning.

Where the commissioning involves several stages and the time between stages is more than eight weeks apart then the results shall be recorded within four weeks of completion of each stage.

The project manager is responsible to ensure that this activity has been completed within the timeframe specified.

Refer to Appendix C for details on ITPs and checklist requirements.
9. Pre-commissioning mandatory requirements

Certain mandatory activities shall be completed prior to the following activities:

- commissioning of a new location (building and associated aspects)
- energisation of HV equipment
- energisation of 1500 V dc equipment
- connection of equipment to the existing RailCorp high voltage distribution network

Commissioning can involve several stages and the mandatory requirements identified in this document may not always be required to be completed at the first stage.

A typical example is the commissioning of a new traction substation. The initial stage is often the energisation of the HV switchboard, with subsequent stages being the 1500 V dc equipment as a sectioning hut, and finally commissioning of the rectifiers.

9.1. Building and associated requirements

Specific commissioning activities are required to be completed prior to the energisation of HV or 1500 V equipment and acceptance of a substation building. This is done to ensure the security of the building, safety of personnel operating and maintaining equipment, and remote monitoring of the building and equipment. These activities are as follows:

- completion of fencing specific to the security of the location and prevention of unauthorised access to restricted areas
- doors and access gates fitted with correct locks
- commissioning of door entry alarms, remote monitoring and CCTV (where installed)
- fire system commissioned
- SCADA system commissioned
- phones commissioned
- low voltage auxiliary supply commissioned or suitable temporary supply available
- normal and emergency lighting commissioned
- BCA safety requirements satisfied
- signage and labelling installed
- forced ventilation system (where installed) commissioned
- drainage pumps (where installed) commissioned
9.2. **Energisation of HV and 1500 V equipment**

Prior to energising equipment at the system voltages the following activities shall be completed:

- verification of the installation by the designer
- testing of the earth system and verification by designer
- commissioning of auxiliary ac supply
- commissioning of auxiliary dc supply
- registering all equipment in the operator and maintainer's equipment and enterprise asset management system
- completing and verifying all ITPs and associated checklists of the equipment to be energised, by the designer
- testing, commissioning and verifying appropriate protection schemes by the protection engineer
- making local instructions and operating manuals available onsite
- making approved electrical operating diagrams available onsite
- type approving of equipment and acceptance by ASA for use on the RailCorp network
- making specialised operating tools available for equipment onsite
- equipment earthing and test equipment in accordance with ENSR requirements in place and available for use
- training authorised personnel on the relevant equipment to satisfy the requirements of ENSR
- training maintenance personnel in the fault finding and maintenance of equipment

10. **Test equipment**

All test equipment used to complete the prescribed tests in this standard shall be designed, manufactured and specifically intended for the test to be performed.

The test equipment shall be calibrated by an appropriate certifying company with calibration records available at the time of testing.
11. **Equipment tests**

A list of typical substation equipment is stated in Section 11.1, Section 11.2, Section 11.3 and Section 11.4 and the associated tests required to be completed by the commissioning engineer.

These tests are in addition to the specific type approval and routine tests that the manufacturer is required to complete in accordance with relevant equipment specific transport standards.

All applicable tests as detailed in this standard shall be completed with satisfactory results. This shall be prior to a new system substation, or a new item of equipment in an existing system substation is placed in service.

11.1. **1500 V dc equipment**

Table 1 details the required tests to be performed for 1500 V dc equipment.

**Table 1 – 1500 V dc equipment tests**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Electrical continuity</th>
<th>Insulation resistance</th>
<th>Operation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 V IRCS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 4.</td>
</tr>
<tr>
<td>1500 V rectifier negative link</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional testing also required. Refer note 4.</td>
</tr>
<tr>
<td>1500 V DCCB (feeder)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional and protection testing also required. Refer note 4 and note 5.</td>
</tr>
<tr>
<td>1500 V DCCB (rectifier)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional and protection testing also required. Refer note 4 and note 5.</td>
</tr>
<tr>
<td>1500 V positive busbar</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Refer note 1</td>
</tr>
<tr>
<td>Rectifier power cubicle</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional testing also required. Refer note 2 and note 4.</td>
</tr>
<tr>
<td>Negative reactor</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 3 and note 4.</td>
</tr>
<tr>
<td>Rail-earth contactor</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer to Section 11.5 for further detail.</td>
</tr>
<tr>
<td>1500 V harmonic filter</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 4.</td>
</tr>
<tr>
<td>Rectifier frame leakage</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 4.</td>
</tr>
<tr>
<td>DCCB frame leakage</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 4.</td>
</tr>
</tbody>
</table>

*Note 1: Electrical continuity test is required across all individual busbar joints.*

*Note 2: Electrical continuity test is required of all connections (cable or busbar) to the 1500 V positive and negative palms.*
Note 3: Electrical continuity test is required of the winding and all connections (cable or busbar) to the reactor palms and associated negative busbar(s).

Note 4: Operation refers to electrical, mechanical and functional operation as applicable.

Note 5: Drop-out test and current trip test (forward for feeder DCCB, reverse for rectifier DCCB) is required to be performed prior to installation at the substation. Drop-out test is required at the location.

11.2. DC auxiliary supply equipment

Table 2 details the required tests to be performed for dc auxiliary equipment.

Table 2 - DC auxiliary equipment tests

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Electrical continuity</th>
<th>Insulation resistance</th>
<th>Operation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 1</td>
</tr>
<tr>
<td>Battery charger</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 1</td>
</tr>
<tr>
<td>Submain and final circuit cables</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Polarity and correct circuit identification tests are also required.</td>
</tr>
<tr>
<td>Distribution board</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: The battery charger float voltage, temperature compensation and alarms are required to be set in accordance with the manufacturer's procedures and local instruction settings. A discharge test is required for all new batteries.

11.3. HV equipment

Table 3 details the required tests to be performed for HV equipment.

Table 3 - HV equipment tests

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Electrical continuity</th>
<th>Insulation resistance</th>
<th>Operation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC outdoor busbar</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Hi-pot test required</td>
</tr>
<tr>
<td>Indoor switchboards</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional and protection testing also required. Hi-pot test required. Refer note 1.</td>
</tr>
<tr>
<td>ABSW</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 2.</td>
</tr>
<tr>
<td>ACCB</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional and protection testing also required.</td>
</tr>
<tr>
<td>Equipment</td>
<td>Electrical continuity</td>
<td>Insulation resistance</td>
<td>Operation</td>
<td>Comment</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
<td>-----------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rectifier transformer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional and protection testing also required. Refer note 3 and 4.</td>
</tr>
<tr>
<td>Auxiliary transformer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer note 4.</td>
</tr>
<tr>
<td>System transformer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional, protection and AVR testing also required. Refer Note 4.</td>
</tr>
<tr>
<td>Harmonic filter</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>System functional and protection testing also required.</td>
</tr>
<tr>
<td>Outdoor voltage transformer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer to protection test requirements</td>
</tr>
<tr>
<td>Outdoor current transformer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Refer to protection test requirements</td>
</tr>
</tbody>
</table>

Note 1: Hi-pot test is required for all new 11 kV, 33 kV and 66 kV switchboards. 11 kV RMU's do not require a hi-pot test. Switchboards that have a modification or repair to the busbar or primary insulation require a hi-pot test at a reduced test voltage.

Note 2: Installed in the RailCorp network are manual, electric or pneumatically operated ABSW. Operational tests will vary for the different types.

Note 3: Electrical continuity test is required of all connections (cable or busbar) to the 600 V palms.

Note 4: All oil used for new transformers and to replace oil in existing transformers is required to be tested and comply with AS1767.1.

11.4. HV and 1500 V dc cables

High voltage and 1500 V dc cables shall be tested in accordance with EP 20 00 00 20 SP Testing of High Voltage and 1500 V DC Cables.

11.5. Rail-earth contactor

The rail-earth contactor (REC) is required to have continuity, insulation resistance and operation tests. The trip operation voltages and associated delay time shall be tested to ensure correct operation as the REC is a safety critical piece of equipment.

11.6. Low voltage light and power circuits

The verification and testing requirements for low voltage light and power circuits shall be in accordance with section 8 of AS/NZS 3000:2007.
11.7. **Emergency lighting (240 V ac)**

The tests for the emergency lighting system (where fitted) shall be in accordance with AS/NZS 2293.2:1995.

11.8. **Automatic auxiliary changeover**

The complete functionality of the automatic changeover shall be tested. This shall include the correct operation of the phase failure relay and the subsequent SCADA alarms.

11.9. **Auxiliary transformer**

The low voltage transformer is required to have continuity and insulation resistance tests.

The output voltage shall be checked with the transformer set to the correct tap on energisation. Phase rotation and phase checks with other auxiliary transformers at the same location are required.

11.10. **Signalling supply polarity**

In addition to the tests required for transformers, changeovers and related equipment for signalling supply, the polarity of the supply shall be tested in accordance with T HR EL 90001 PR *Polarity of AC Signalling Supplies*.

12. **System tests**

The following system tests are required and are in addition to individual equipment test requirements detailed in Section 11:

- earthing system
- SCADA system
- rectifier transformer, rectifier, HV ACCB and 1500 V DCCB as a system
- 1500 V feeder DCCB intertrip scheme
- high voltage supplies
- high voltage indoor switchboards
- high voltage protection schemes
- fire protection system
- lighting system
- security and substation access
• drainage pumps
• ventilation systems
• HV harmonic filter system
• electromagnetic compatibility
• communication system
• energy metering (bulk supply point interfaces)

12.1. Earthing system

The earthing system is a safety critical system that requires comprehensive testing and verification to ensure the design model is verified and the substation is safe to be energised.

All new substations require current injection test (CIT), electrode resistance and electrical continuity tests to be completed.

Where an existing earthing system has been modified, CIT is required under one of the following conditions:

• the fault level has increased
• the protection clearing times have increased
• the revised earth model results reflecting the modification to the earthing system result in a 10% reduction in safety margin
• the earthing designer has specified that a CIT is required as result of hazard and risk assessment

12.1.1. Current injection test

This test shall be completed using the off 50 Hz frequency method and is used to measure the following:

• earth grid potential rise
• current splits (magnitude and angle)
• standalone earth grid resistance
• combined earth system resistance
• step and touch voltages
• transfer voltages
Where the substation high voltage feeders consist of cable at the switchgear and transitions to aerial line, then the step and touch voltages at the UGOH and at the aerial line poles that have earth down leads are required to be measured.

12.1.2. Electrode resistance

Individual electrode resistance values shall be measured and recorded using the clamp-on resistance measurement method. This is required for all electrodes including the electrodes at the UGOH and at the aerial line poles that have earth down leads. Each electrode shall be uniquely identified with the corresponding resistance recorded. This will form the baseline maintenance data.

12.1.3. Earth continuity tests

All equipotential bonding connections (equipment bonds, earth braids for fences, gates, air break switches, water pipe bond and so on) shall have continuity tests to verify their electrical connection.

12.2. SCADA system

The functions of the SCADA system can be split into either supervisory control of equipment or data acquisition.

The typical data from equipment located in a substation that is conveyed to the SCADA system includes the status of equipment, equipment and system alarms and measurement of parameters (current, voltage and temperature). The typical control of equipment is the position of ACCBs, 1500 V DCCBs, REC and rectifier tap changer position.

The following tests and simulations are required:

- confirmation of individual alarms from the source equipment to the EOC
- verification of hardwired alarms to ensure they are sourced from the correct battery (positive and negative) and connected to the RTU I/O card connected to the same battery
- operation of equipment which typically includes HV ACCBs, disconnectors, earth switches, 1500 V DCCBs, 1500 V rectifier negative link and transformer tap changers to confirm the position indication at EOC
- simulation of analogue data as close as possible to the source to confirm correct scaling factors, polarity and display at EOC
  The test shall be completed at the extreme ranges and median value.
- verification of kWhr metering
- EOC operation of equipment to and from all states
12.3. **Rectifier transformer, rectifier, HV ACCB and 1500 V DCCB as a system**

Numerous interfaces between the rectifier transformer, rectifier, HV ACCB and 1500 V DCCB are required to be tested to ensure the correct operation as a system. The correct operation of the protection and control logic is critical.

12.3.1. **Protection**

The protection tests for the rectification equipment as a system shall be in accordance with EP 03 02 00 01 SP *Controls and Protection for Rectification Equipment*, Table 1.

12.3.2. **Control**

The control logic shall be tested in accordance with EP 03 02 00 01 SP *Controls and Protection for Rectification Equipment*, Section 5.2.6 for the following situations:

- where the HV ACCB is located in an outdoor yard
- there is a rectifier control panel located adjacent to the rectifier (such as in the older RailCorp substations)
- there is a duplicated rectifier control panel (example, 66 kV GIS locations)

12.3.3. **Energisation tests**

The output voltage shall be checked for magnitude and polarity before placing into service upon energisation of the complete rectifier.

When the rectifier is placed into service the ammeter and voltmeter shall be checked to ensure that the unit is functioning correctly.

12.4. **1500 V feeder DCCB intertrip scheme**

Requirement for this scheme to be installed is specified in the approved power study. The scheme relies on the correct operation of the intertrip protection relay, 1500 V DCCBs at both ends of the section, the communication system and the substation or sectioning hut auxiliary supply.

The following tests are required:

- communication system tests
- intertrip send/receive and subsequent tripping of DCCBs
- SCADA alarm verification from all devices

The designer shall specify the detailed testing procedures.
12.5. **High voltage supplies**

Appropriate phase checks are required when HV equipment is required to be connected to the RailCorp high voltage distribution network. This includes the following:

- phase check of busbars of indoor HV switchboards and outdoor HV busbars
- phase check of secondary voltage of system transformers
- auxiliary transformers at the same location are required to be in phase
- signalling supplies are required to be in phase
- voltage transformers on switchboards are required to be in phase with each other

12.6. **High voltage indoor switchboards**

The commissioning of HV indoor switchboards requires several subsets of equipment and systems to be tested prior to energisation as follows:

- SCADA system
- dc auxiliary system
- all operational and functional testing of the switchboard
- earthing system
- busbar protection scheme (where installed)
- arc light detection scheme (where fitted)
- protection schemes directly associated with the equipment connected to the ACCBs to be commissioned
- gas alarm and interlocking scheme (where installed)
- labelling to be verified against the current approved ac operating diagram for the location

12.7. **High voltage protection schemes**

Table 4 details the required protection tests to be performed for the particular equipment category.

The functional tests of the protection scheme include full operation checks on the protection relay, all associated multi-trip of ACCBs (including intertripping), differential protection scheme tests, trip circuit supervision tests and the simulation and commissioning of SCADA alarms (hardwired and serial link).
Table 4 – HV protection tests

<table>
<thead>
<tr>
<th>Equipment</th>
<th>CT 2ry wiring (note 1)</th>
<th>CT Polarity</th>
<th>CT Ratio</th>
<th>CT Knee point</th>
<th>Primary injection</th>
<th>Functional tests of scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of indoor HV switchboard</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Installation of outdoor HV ACCB (dead tank)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Installation of outdoor HV ACCB (live tank)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Refer note 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation/replace of CT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rectifier transformer frame leakage and system transformer neutral leakage</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Replacement of protection relay</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Refer note 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: The CT secondary wiring tests include measurement of the CT secondary winding resistance and insulation resistance measurement. The insulation resistance measurement is to include the CT secondary winding and CT secondary leads (refer to Appendix A).

Note 2: These requirements are applicable for the replacement of an ACCB only and the associated CT secondary wiring is not routed via the ACCB.

Note 3: These requirements are applicable to withdrawable protection relays only and there is no connection or disconnection of secondary or auxiliary wiring.

Note 4: Secondary injection is required as one of the functional tests to confirm the relay settings.

12.8. Fire protection system

The fire protection system shall be tested and certified by the authorised manufacturers’ representative. As a minimum these tests should include the following:

- activation of individual detectors (smoke test) and identification of detector and associated zone
- calibration and setting of alarms and thresholds
- confirmation of display diagnostics
• testing of output relays to confirm configuration
• activation of local audible and visual warnings

The commissioning engineer shall test the following:
• dc polarity, correct circuit allocation to low voltage distribution board
• SCADA alarms received by EOC and identified correctly

12.9. Lighting system

The electrical aspects of the lighting system shall comply with the relevant low voltage tests as prescribed in this document.

The other tests required are as follows:
• measurement of the lighting level to verify the design requirements
• positional check of light fittings to ensure the lighting is suitable for the intended purpose
  This is to ensure that the lighting is positioned to minimise shadows and ensure the light coverage is consistent on equipment required to be operated and maintained.
• functional check of ac and dc emergency lighting to ensure correct activation
• correct operation of daylight sensors (where fitted)

12.10. Security and substation access

All substation entry doors that are required to be monitored shall be verified for the following:
• SCADA alarm is received at EOC upon minimal opening of the door
• substation siren is activated upon opening of the door
• substation siren is silenced by personnel reset switch
• SCADA alarm received by EOC is reset upon the door being closed

12.11. Drainage pumps

Where automatic drainage pumps are installed the system shall be tested to ensure the following:
• correct initiation of the pump for the designed activation level
• correct cessation of the pump when designed level reached
• all SCADA alarms are operational and received by EOC
• drainage system is not blocked
12.12. Ventilation systems

The ventilation system design and installation is required to be validated by recording temperature readings and entering this data into the model. This is applicable for both passive and active ventilation systems.

Where an automatic ventilation system is installed the system shall be tested to ensure the following:

- correct initiation of the system for the designed activation level
- correct cessation of the system when designed level reached
- all SCADA alarms are operational and received by EOC

12.13. Electromagnetic compatibility (EMC)

Where the substation is located in the vicinity of an EMC sensitive site or equipment then EMC testing is required to validate the design and subsequent construction.

As the substation is a source of emissions and the level of emissions varies with the electrical load, the testing shall be completed at different loads.

12.14. Energy metering (bulk supply point interfaces)

Where a substation interfaces with a bulk supply point, the energy metering is required to be tested and certified by the metering provider in accordance with the requirements of the National Electricity Rules and the Local Network Service Provider.

12.15. HV harmonic filter system

The HV harmonic filter system shall be commissioned by the manufacturer and commissioning engineer to ensure the following:

- correct operation of the interlocking with the HV ACCB, filter discharge earth and the harmonic filter enclosure
- correct operation of protection relay(s) and associated tripping of ACCBs and SCADA alarms produced
- correct tuning of HV filter and automatic adjustment (where fitted) is functioning correctly
- analogue and SCADA alarms are conveyed to EOC
12.16. Communication system

The AEO’s communication engineer shall certify the fibre communication system to ensure that the system is suitable for use by the SCADA system, line differential protection schemes, dc intertripping schemes, VOIP phone system and WAN port.
Appendix A - Insulation resistance values

Table 5 shows the minimum acceptable insulation resistance values for equipment. These values do not apply to HV and 1500 V dc cables. Refer to EP 20 00 00 20 SP Testing of High Voltage and 1500 V DC Cables for more information.

Table 5 – Minimum acceptable insulation resistance

<table>
<thead>
<tr>
<th>Equipment and voltage</th>
<th>Test voltage of insulation resistance meter (1 minute test duration)</th>
<th>Minimum acceptable value in dry conditions @ 20° C</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 kV and above</td>
<td>5 kV</td>
<td>100 MΩ</td>
</tr>
<tr>
<td>1500 V dc (includes 600 V rectifier auxiliary transformer windings)</td>
<td>2.5 kV</td>
<td>20 MΩ</td>
</tr>
<tr>
<td>415/240/120 V wiring</td>
<td>500 V</td>
<td>1 MΩ</td>
</tr>
<tr>
<td>CT secondary wiring - new installation</td>
<td>500 V  Refer note 1</td>
<td>5 MΩ</td>
</tr>
<tr>
<td>CT secondary wiring - existing installation</td>
<td>500 V  Refer note 1</td>
<td>1 MΩ</td>
</tr>
</tbody>
</table>

Note 1: This value is applicable to CT secondary wiring with a maximum voltage rating of 0.6/1 kV.

Insulation resistance is a function of temperature. Values measured at other than 20° C can be converted to 20° C.

Table 6 shows the conversion of insulation resistance temperature.

Table 6 - Insulation resistance temperature conversion

<table>
<thead>
<tr>
<th>Temperature at which measurement made</th>
<th>Multiply measured resistance value by</th>
</tr>
</thead>
<tbody>
<tr>
<td>10° C</td>
<td>0.5</td>
</tr>
<tr>
<td>30° C</td>
<td>2.0</td>
</tr>
<tr>
<td>40° C</td>
<td>4.0</td>
</tr>
<tr>
<td>50° C</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Appendix B - Electrical continuity test values

Table 7 shows the maximum acceptable resistance of closed contacts and busbar joints.

The minimum test current is 100 A.

<table>
<thead>
<tr>
<th>Nominal equipment voltage</th>
<th>Resistance @ 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 V dc</td>
<td>20 μΩ</td>
</tr>
<tr>
<td>11 kV</td>
<td>30 μΩ</td>
</tr>
<tr>
<td>33 kV and above</td>
<td>100 μΩ</td>
</tr>
</tbody>
</table>
Appendix C - ITP and checklist documentation requirements

The ITPs and associated checklists that are produced and completed for the testing and commissioning are important documents for the assurance of the equipment and associated systems.

The recorded data from the testing and commissioning establishes the baseline that can be used for the ongoing monitoring and condition assessment.

The following minimum information shall be included:

- ITP and checklists individually numbered and under version control
- Name of all signatories printed and signed along with position and company
- Details of testing equipment recorded (manufacturer, model number, serial number)
- Date of testing
- Temperature and weather conditions for tests that require measurement of electrical parameters
- Location and identification of equipment and/or system that is being tested
  Identification includes the equipment serial number.
- Activity/description with appropriate testing criteria clearly identified and appropriate units specified
- Measured values recorded with unit of measurement
- Pass or fail column for measured criteria
- References to drawings, related ITPs, related checklists as required