T HR EL 11004 ST

Standard

Electrical SCADA Interface Requirements

Version 2.0

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Important message

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

Standard governance

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Document history

Version	Summary of changes
1.0	First issue, 13 December 2016.
2.0	Removed some preferences and replaced with mandatory requirements. Added Section 6.3.1 concerning master station alarms. Updated to reflect a change in SCADA master station supplier.

Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the *ASA Charter*, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW's process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW’s Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

The purpose of this document is to set out the requirements for interfaces to the electrical supervisory control and data acquisition (SCADA) system and for commissioning those interfaces.

The standard requirements for the most common interfaces to the SCADA system on the TfNSW Metropolitan Heavy Rail Network (formerly known as the RailCorp network) are covered in this document.

This is a second issue.

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1. Introduction

Various locations on the TfNSW Metropolitan Heavy Rail Network require monitoring or control by the electrical supervisory control and data acquisition (SCADA) system. To ensure that all of the locations interface to the system consistently, a standard set of requirements is necessary. Interfaces to the SCADA system occur between field equipment and the remote terminal unit (RTU), and between the RTU and the master station.

Correct commissioning of SCADA points is critical to maintaining the SCADA system's reliability and integrity and for recording data and event information.

2. Purpose

The purpose of this document is to set out the requirements for interfaces to the electrical SCADA system and for commissioning those interfaces.

2.1. Scope

The standard requirements for the most common interfaces to the electrical SCADA system on the TfNSW Metropolitan Heavy Rail Network are covered in this document.

Refer to TS TOC 1 *Train Operating Conditions (TOC) Manual – General Instructions* which defines the areas associated with the network.

2.2. Application

This document applies to all equipment that interfaces to the electrical SCADA system on the TfNSW Metropolitan Heavy Rail Network.

This standard is intended to be used by Authorised Engineering Organisations (AEOs) that undertake work on the SCADA system related to the RTU and the master station.

This standard shall be read in conjunction with T MU EL 11003 ST *Electrical SCADA System*.

3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

Transport for NSW standards

EP 00 00 00 13 SP Electrical Power Equipment - Design Ranges of Ambient Conditions

EP 00 00 00 15 SP Common Requirements for Electric Power Equipment

T HR EL 10002 ST HV Aerial Lines - Standard Conductors and Current Ratings

T HR EL 11001 PR Design Technical Reviews for Electrical SCADA Equipment

T HR EL 11001 TI SCADA Standard I/O Schedule

T HR EL 11002 SP Electrical SCADA System Remote Terminal Unit

T HR EL 20001 ST High Voltage ac and 1500 V dc Traction Power Supply Cable Requirements

T HR EL 20002 ST 1500 V DC Cables and Cable Ratings

T HR EL 90002 ST Heavy Rail Traction System - Voltage Ratings

T HR EL 90003 ST Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment

T HR EL 99001 ST Substation and Sectioning Hut Commissioning Tests and Processes

T HR TE 21003 ST Telecommunications for Traction Substations and Section Huts

T MU EL 11003 ST Electrical SCADA System

TS TOC 1 Train Operating Conditions (TOC) Manual – General Instructions

TfNSW drawings

MET RL 0363 Communications Cabinet for HV Locations – Typical Arrangements

(Available on request to Central Planroom)

4. Terms and definitions

The following terms and definitions apply in this document:

ACCB alternating current circuit breaker

AEO Authorised Engineering Organisation

CT current transformer

DCCB direct current circuit breaker

DNP3 distributed network protocol

ESO electrical system operator

HMI human machine interface

IED intelligent electronic device

I/O input or output

Modbus communication protocol developed by Modicon in 1979 and now managed by the Modbus Organisation

MMOF multi-mode optical fibre

PLC programmable logic controller

rms root mean square

RS485 multipoint communications standard set by the Electronics Industry Alliance and Telecommunications Industry Association

RTU remote terminal unit

SCADA supervisory control and data acquisition

TfNSW Transport for NSW

U_{max1} highest permanent voltage; the maximum value of the voltage likely to be present indefinitely

U_{max2} highest non-permanent voltage; the maximum value of the voltage likely to be present for maximum five minutes

U_{min1} lowest permanent voltage; the minimum value of the voltage likely to be present indefinitely

U_{min2} lowest non-permanent voltage; the minimum value of the voltage likely to be present for maximum five minutes

5. Interfaces

Section 5.1 and Section 5.2 specify the common interfaces between remote terminal units (RTUs) and the master station, and also between RTUs and field equipment.

5.1. RTU interfaces to the master station

Section 5.1.1 to Section 5.1.3 describes the interfaces at different locations.

5.1.1. Standard RTU communications

RTUs located in substations, sectioning huts and electrical installation locations shall have a standard communication interface. The SCADA master station shall interface with the RTUs utilising private virtual circuits on the communications network used by the operator using distributed network protocol (DNP3) level two (minimum) over ethernet. RTUs shall communicate through dual ethernet ports (A and B port) to the communications network. The patch leads connect to a communications switching panel within the substation. Typically RTUs use 10BaseFL multi-mode optical fibre (62.5 µm or 125 µm) patch leads and media converters or dual 100BaseFX ports connected directly into the communications switching panel (not using media converters). See Appendix D.4 for a diagram showing communication cabling for an RTU.

The communication arrangement shall be in accordance with T HR TE 21003 ST *Telecommunications for Traction Substations and Section Huts*.

Note: The RTU is supplied using 125 V dc (50 V dc in some locations) from the substation battery. The communication cabinet and equipment are supplied by

48 V dc from the RTU using two 125/48 V dc/dc converters (one for each communications switch). Refer to T HR EL 11002 SP Electrical SCADA System Remote Terminal Unit for more information.

5.1.2. Compact RTU communications

Metallic input or output (I/O) wiring shall not extend outside the substation boundary beyond the location's earth grid. Refer to T HR TE 21003 ST for communications wiring.

The I/O shall be connected to the master station through a compact RTU at locations such as the following:

- 1500 V dc field switches
- spark gaps (Ferraz units)
- compressor rooms
- pumping stations
- generator rooms
- station walkway access
- other equipment with small amounts of I/O away from electrical locations

The compact RTU shall be connected to the nearest substation RTU. The protocol used is dependent on the type of the two RTUs (most RTUs installed use proprietary protocols for slave RTUs). DNP3 over optical fibre shall be used where it is an available protocol. For Foxboro RTUs, this link uses optical fibre with the following specifications:

- 62.5/125 µm multi-mode fibre
- 8 cores (4 used with 4 spare)
- less than 500 m long
- SC connectors

See Appendix D.5 for a diagram showing an example of the cabling for a pumping station location.

If the communication link mentioned above cannot be installed, due to distance or location, then the RTU shall connect directly to the master station using DNP3 via communication network switches (A and B) with single-mode fibre to the nearest communications network node. This communication arrangement shall be in accordance with T HR TE 21003 ST.

For situations where there are less than five digital inputs, contact closure devices which convert copper to optical fibre may be used provided they are type approved by TfNSW. Consideration shall be given to power requirements and device monitoring as it can be more beneficial to install an RTU in most situations.

5.1.3. Compact RTU and cabinet

A compact RTU shall be used to monitor equipment with a small amount of I/O and shall consist of the following:

- a processor card (this can be combined with I/O and power supply on one card)
- two I/O cards
- a power supply card
- marshalling terminal strips
- optical fibre terminations
- general power outlet
- external power supply (normally 240 V ac)
- 240 V ac relay (to provide isolation for the ac fail alarm)

If a risk assessment determines that the indications or controls need to be available when normal power supplies are unavailable, then a battery shall be installed in accordance with T HR EL 11002 SP *Electrical SCADA System Remote Terminal Unit*. The battery voltage shall be monitored by the RTU.

The RTU shall be housed in a stainless steel cabinet in a 'safe place'. There should not be a need to pass through the danger zone to gain access to the RTU. The size of the RTU cabinet shall be at least 800 mm high x 400 mm wide x 350 mm deep (this allows room for cables extending horizontally from the RTU). See Figure 1 for an example of a compact five slot RTU (central processing unit card plus five I/O slots) with batteries.

Figure 1 - Example RTU and cabinet for 1500 V dc field switches

5.2. Equipment interfaces

Section 5.2.1 and Section 5.2.2 detail the requirements for common interfaces between field equipment and RTUs.

5.2.1. Protection relays, intelligent electronic devices and other serial devices

Serial devices, including protection relays, rectifier control programmable logic controllers (PLCs) and battery chargers connected to an RTU shall be able to communicate in a medium and format compatible with that RTU. DNP3.0 (level 2) over RS485 shall be used where it is an available protocol. However, the Modbus RTU protocol over RS485 is also permissible. The RS485 bus shall be a daisy chain arrangement for each switchboard section. The cable screen shall be connected to earth at the RTU end only.

All serial I/O shall be specified in the location's I/O schedule with addressing details. Refer to T HR EL 11001 PR *Design Technical Reviews for Electrical SCADA Equipment* and T HR EL 11001 TI *SCADA Standard I/O Schedule* for more information. Virtual indications from one device shall be configured in such a way that if the serial communications fail, then all the indications on that master station channel will be marked as failed by the master station.

Note: The Modbus address is related to the RTU port number – the first address on port 1 is 10 and the second address on port 2 is 21.

For devices using DNP3.0, time stamping shall be done at the intelligent electronic device (IED) with the time being synchronised with the RTU with +/-2 ms accuracy. For devices using Modbus protocol, time stamping shall be done at the RTU.

RS485 wiring shall be single pair twisted, shielded, minimum 0.4 mm^2 instrumentation cable. It shall be terminated at the last IED with a 0.5 W 120 ohm resistor to match the cable impedance. The outer sheath should be black with a black insulated core and a white insulated core. The wiring shall meet the requirements of EP 00 00 00 15 SP *Common Requirements for Electric Power Equipment*.

Westermo ODW-631 or similar RS485 to multi-mode converters shall be used to communicate between RTUs and the rectifier control PLCs.

5.2.2. Hardwired I/O

Hardwiring is where copper wiring is used to directly connect each indication and control to the RTU via the RTU marshalling cubicle. All hardwired I/O wiring shall have stranded cores to reduce the likelihood of breakage and meet the requirements of EP 00 00 00 15 SP.

See the diagrams in Appendix D for more information about indication wiring.

Analogue inputs

Hardwired analogue inputs to RTUs shall be fully isolated dc current loops (0±20 mA, 0±10 mA, 4 mA to 20 mA), being primarily unipolar depending on the application.

Current loop details are as follows:

- overall shielded twisted pairs
- shield connected at the RTU end only, to reduce interference (the unterminated shield shall be cut and covered with insulating material)
- maximum loading 1 k ohm
- minimum wire size 0.5 mm^2 (7/0.30), preferred 1.5 mm^2 (7/0.50), stranded, instrumentation cable
- black outer sheath with a black insulated core and a white insulated core (preferred)

Bipolar analogue examples are as follows:

- dc feeder currents
- temperatures
- rail earth contactor (REC) volts
- energy or power

Analogue input accuracy

The accuracy of analogue inputs from source to master station shall be equal to or better than ±1% (except for 1500 V dc currents which shall be equal to or better than ±5%) over the full scale and for the temperature range specified in EP 00 00 00 13 SP *Electrical Power Equipment - Design Ranges of Ambient Conditions*. The RTU equipment (resistors, analogue to digital converter and software accuracy) shall have accuracy better than 0.25%.

Individual analogue requirements

Table 1 specifies particular requirements for certain analogue inputs.

Table 1 - Individual analogue requirements

Analogue point	Comments
ac current	0 mA to 20 mA inputs. Only B phase is connected to SCADA. Current transducers are typically 1 A/20 mA for newer locations and 5 A/10 mA or 5 A/20 mA for older locations
ac voltage	Phase-phase volts. Only C-A phase voltage is monitored. Voltage transducers are 125 V/20 mA as voltage transformer ratios are 75 kV/125 V (66 kV/110 V) or 37.5 kV/125 V (33 kV/110 V) or 12.5 kV/125 V (11 kV/110 V)

Analogue point	Comments
dc feeder current	See Appendix A.1
dc voltage	Unipolar with an output of 20 mA
Ambient temperatures	Transducers have a 4 mA to 20 mA range
Transformer temperatures	Oil and winding temperatures are unipolar (0 mA to 20 mA equals 0 °C to 150 °C)
Rectifier air temperatures	Unipolar (0 mA to 20 mA equals 0 °C to 80 °C)

Digital inputs

Digital inputs can be of the active or passive type. Passive inputs source the battery system positive from the RTU 'alarm bus', which is protected by a two amp fuse. Active inputs source the battery system positive from the field equipment. Active inputs shall be used wherever the battery system positive is available in the field equipment. The battery system negative shall be sourced from the RTU for both active and passive inputs.

Field equipment alarm indications shall present to the RTU a contact that is normally closed when the equipment is in the normal state (fail-safe). There are exceptions for some equipment where the indication has a voltage 'high' when it is in the alarm state. These exceptions are listed in T HR EL 11001 TI. The contacts and wiring shall be rated for the substation system battery voltage.

Note: RTUs limit the input current to 4 mA. Field equipment design modifications may be required as field equipment relays may require more than 4 mA to remain closed.

Digital inputs shall be compatible with the RTUs digital input threshold voltage. The threshold voltage, where the input changes from low to high or high to low, is between 35% and 65% of the nominal system battery voltage.

If the indication voltage is outside the RTU's digital input voltage range then an interposing relay shall be used. This is the case for the substation fire alarm panel. For locations where there are two battery systems, digital inputs shall be clearly labelled to identify which battery system is used.

Field wiring shall be multi-stranded cable with a cross sectional area of between 0.75 mm^2 and 2.5 mm^2, with the preference being 1.5 mm^2 (7/0.50). The outer sheath should be orange with white, insulated, numbered cores.

Digital outputs (controls)

The RTU provides voltage free contacts rated for switching so that the field equipment can be fully isolated from all sources of supply including the RTU. For non-latching outputs, the RTU contacts close for a maximum of 2 s.

Loads shall be less than the following:

- 1 A inductive at 125 V dc
- 1 A inductive at 50 V dc
- 1 A inductive at 24 V dc

Appropriate relays shall be selected for the specific type of load. The minimum contact whetting current shall be delivered to the RTU (10 mA for most RTUs).

Two wires are required in the field cabling for each control, except for direct current circuit breakers (DCCBs), which are not in metal enclosed switchboards, which use single-wire controls to maintain system-wide compatibility. Supply for these DCCB controls is from the RTU 'control bus' which is protected by a two Amp fuse. DCCBs in metal enclosed switchboards shall use two wire controls with the supply from the DCCB panel.

Control field wiring shall meet the requirements of EP 00 00 00 15 SP except that the stranding can be 7/0.50. Control wiring shall be in separate cables to digital input wiring.

Individual digital output requirements

Table 2 specifies particular requirements for certain digital outputs.

Table 2 - Individual digital output requirements

Digital output	Comments
Metal enclosed DCCBs	The +125 V dc supply is derived from the DCCB. The negative connection for the control circuit is also made at the DCCB. The controls shall use two wires.
Non-metal enclosed DCCBs	A +125 V dc supply is derived from a control bus in the RTU marshalling panel which is wired to the DCCB through the RTU output relay contact. The negative connection for the control circuit is made at the DCCB (there is no return to the RTU).
Tap changers	Tap changer controls shall use four wires (two for the raise control and two for the lower control).
Alternating current circuit breakers (ACCBs)	ACCB controls use two wires with interposing relays (in the ACCB) to reduce the amount of current to the RTU control relays.

Note: Older tap changer controls use three wires for each up and down control pair.

Note: 52SO devices are used in older equipment as interposing devices in ACCBs. RTU relays are rated at 10 A at 125 V dc which is sufficient for most locations with older equipment. However, the trip circuit current can sometimes be up to 30 A.

6. Commissioning interfaces

Testing and commissioning is the formal process of validating and documenting that the installed SCADA system complies with and performs in accordance with the design documentation. The validation criteria should be defined during the design stage.

In addition to SCADA requirements, the electrical system operator (ESO) requirements for instructions and procedures for new indications and controls shall be complied with. Equipment commissioning shall not occur until the ESOs have all the necessary documentation.

6.1. General commissioning requirements

For SCADA commissioning, enough time shall be allowed to check field equipment and correct faults before it is put into service. An organised system of creating and maintaining commissioning documentation, including I/O schedule, cable schedule, commissioning checklist, single line diagram and equipment diagrams shall be used.

End to end testing, where field equipment status is used to change the indication on the master station human machine interface (HMI), shall be performed wherever possible to ensure system integration. See T HR EL 11001 PR for more information about commissioning.

Whenever all or part of a SCADA system is modified, repaired or replaced, testing is required to verify that the modifications function correctly and that the work has not affected other parts of the system. The extent of re-commissioning shall be determined from the extent of the modifications and the risk to the system.

The maintainer's electrical operating centre shall be advised of points that are to be made operational before field equipment commissioning. The SCADA system shall be commissioned before energising HV equipment as required in T HR EL 99001 ST *Substation and Sectioning Hut Commissioning Tests and Processes*.

6.1.1. Documentation

The I/O schedule shall be used to create the commissioning checklist to include all I/O. The checklist is a record of each test and shall state if the equipment was operated or a simulation performed during the test. A commissioning checklist shall be available at the maintainer's electrical operating centre and at the field location. The checklist shall include the location and the name of the person testing and shall be dated, signed and have comments where necessary. Prior to field equipment commissioning, the required SCADA points are certified by the commissioning manager and the SCADA engineer as operationally ready and are put into service.

The records at the master station shall also include the function of the following on the master station:

- audible alarm
- alarm and event list entry
- analogue recording and analogue error

See T HR EL 11001 PR for a sample commissioning checklist. SCADA commissioning records shall be stored with the full set of substation commissioning documents in the maintainer's enterprise asset management system when completed. See T HR EL 99001 ST for more information on tests and processes for commissioning.

After commissioning SCADA and field equipment, the commissioning engineer shall prepare a list of uncommissioned field equipment indications and controls. This defects list shall show all outstanding items, including those that have not been tested and those that have failed. This condition shall be shown on the master station with a modification to the equipment symbol, such as a tag or comment. The defects list shall include an explanation of the issue, the expected corrective action, expected completion date and the responsible party. Outstanding items shall be managed by the commissioning engineer or project manager and shall be corrected as a matter of urgency.

6.1.2. Master station

The maintainer shall maintain and use a procedure that details the transfer of responsibility for equipment on the SCADA system between the operator's SCADA engineering section and the electrical operating centre.

The procedure shall document the following where necessary:

- identification of equipment and associated I/O
- date when the equipment is expected to be in service
- detail how points are annunciated and their status prior to being put into service
- specify modifications to the equipment symbol to be used to identify the point status
- detail how the operator's SCADA engineering section is advised of the success or otherwise of each point that was commissioned

Appendix B contains a sample master station commissioning form.

6.2. Analogue inputs

Table 3 contains important information to consider when commissioning common analogue inputs.

Table 3 - Considerations when commissioning common analogue inputs

Point description	Comment
Ambient or cubicle temperature	Check 4 mA is zero for 4 mA to 20 mA inputs
HV ac current	Inject test current, confirm current transformer (CT) ratio
11 kV, 33 kV, 66 kV voltage	Test up to 12.5 kV, 37.5 kV, 75 kV using 125 V ac input

Point description	Comment
1500 V dc current	See Appendix A
Rectifier ac current summation	Test using multiple simulated inputs to RTU
Equipment temperature (rectifier, transformer and reactor)	Test and confirm alarm value
Rectifier transformer tap changer position	Change tap position to confirm value

Analogue inputs shall be tested as close as possible to the source, with the testing point recorded. The input value and the actual master station value shall be recorded to calculate the accuracy (see Appendix A for more information). Values to be tested shall be at least zero, the highest expected value (the engineering maximum) and the mid-point. If the analogue is bipolar then negative values shall be tested as well.

6.2.1. Analogue point dead band setting

On the SCADA master station, the dead band should be set appropriately, but not be more than 1%, so that the actual analogue value changes are not missed. The dead band will cause any changes in the analogue value within the set range to be ignored.

6.2.2. Analogue limits

Processes need to be followed by AEOs to ensure that electrical SCADA analogue alarms are managed appropriately. These processes cover calculating, configuring and acting on analogue alarms generated by the electrical SCADA system.

These processes shall be implemented for all new 1500 V dc voltage analogues, 1500 V dc current analogues and HV ac feeder current analogues. Previously installed analogues of these types shall be reviewed, prioritised based on loading and modified to meet these processes.

Any limit not specified shall be disabled. The logic routines specified shall be used where available.

HV ac analogue alarms

The following process details the development of HV ac analogue alarms from design to operation:

a. Design of ac current ratings for analogue limits

   The continuous rating of the equipment (for example, conductors, circuit breakers and current transformers) is determined for both summer and winter for each portion of the feeder. Refer to T HR EL 10002 ST *HV Aerial Lines - Standard Conductors and Current Ratings* and T HR EL 20001 ST *High Voltage ac and 1500 V dc Traction Power Supply Cable Requirements* for aerial line and cable requirements.

   The lowest value is the feeder rating, which is entered into the feeder data book.

b. Configuration of ac current analogues

The feeder maximum continuous summer day rating from the design (according to T HR EL 10002 ST for aerial feeders or T HR EL 20001 ST for cable feeders) or the feeder data book, available from Sydney Trains' Engineering and System Integrity section, is used as a configuration setting on the SCADA system for the high limit value. This rating shall be included as a comment in the I/O schedule by the designer for use by the SCADA engineer. This means that ESOs do not need to refer to network configuration documents such as the feeder data book.

For feeders where the high limit alarm has occurred, logic shall be used to calculate the 30 min rms value which shall be alarmed without a delay. For points where the high limit alarm has never occurred, the master station's analogue alarm delay function (explained in Appendix E) shall be used since the SCADA master station's one second rms values cannot correlate with the 30 min rms feeder rating. The delay time shall be set to 10 s as irrelevant peak values generally only stay over the limit for one sample.

For a point already in service, if the existing high limit value is greater than the rating or if the alarm occurs repeatedly without the feeder current approaching the rating then it shall be a point that has a calculated 30 min rms value.

The low limit value shall be set to -2 A to prevent an alarm at zero Amps.

c. HV ac analogue currents in operation

For 30 min rms calculated points, when the alarm occurs the feeder should be de-energised or the network rearranged to reduce the feeder load to within the rating after discussion with the Sydney Trains' Electrical Network Manager. For other points, the SCADA system's 1 s rms value can only provide a prompting for further checks. Therefore, when the alarm occurs, the 30 min rms value shall be checked by using the historian. If the 30 min rms value is greater than the rating (the high limit value), then the feeder should be de-energised or the network rearranged to reduce the feeder load to within the rating after discussion with the Sydney Trains' Electrical Network Manager. Otherwise, the feeder current should be monitored and, if further alarms occur, the 30 min rms check should be performed every 30 min.

When deciding the course of action, consider if the feeder has a fire and life safety concern (for example, it is in a tunnel or it supplies underground stations).

As an input from design, the high limit value should not be changed by ESOs, but be referred to the Sydney Trains' Electrical Network Manager if it does become necessary to change. Any configuration change shall be noted on the SCADA system, if capability exists, and in a network configuration document such as the feeder data book.

1500 V dc analogue alarms

The following processes detail the development of 1500 V dc analogue alarms from design to operation:

a. Design of 1500 V dc feeder currents

The DCCB overcurrent setting is calculated during design and is normally set to a value between 3000 A and 6500 A.

Refer to T HR EL 90003 ST *Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment* and T HR EL 20002 ST *1500 V DC Cables and Cable Ratings* for further information.

b. Design of 1500 V dc voltages

The design of 1500 V dc voltages shall be in accordance with T HR EL 90002 ST *Heavy Rail Traction System - Voltage Ratings*.

c. Configuration of 1500 V dc feeder currents

For 1500 V dc feeder current analogue alarm limits on the SCADA master station, set the high limit value to 90% of the DCCB overcurrent setting, available from Sydney Trains' Engineering and System Integrity section, and the low limit value to the negative value of the high limit, both with a delay of 10 s to prevent events from occurring for short digressions over the limit. This overcurrent setting shall be included as a comment in the I/O schedule by the designer for use by the SCADA engineer. As the DCCB is set based on overload and automatically recloses, it is not necessary for the 1500 V dc feeder current to produce an audible or visual alarm. It needs only to produce an event that can be analysed later to help determine whether the DCCB setting needs to be modified.

d. Configuration of 1500 V dc voltage analogues

For all 1500 V dc voltage analogue alarm limits on the SCADA master station, set the high limit value to 1950 V. The alarm shall have a delay of 10 s so that a digression of a few samples will not produce an alarm. Set the very high limit value to 2000 V with a delay of 10 s.

For rectifier 1500 V dc voltage analogues, the low limit value cannot be set to U_{min1} or U_{min2} as an alarm will be raised when the rectifier is offline for three months. Therefore, the low limit value shall be set to -2 V. This will avoid an alarm being generated for a slightly negative value. Due to errors in the circuitry, when the voltage is 0 V, it can read slightly negative (for example, -0.7 V) on the master station. Logic shall be used where possible to enable low limit alarms when the rectifier is in service.

For 1500 V dc feeder voltage analogues, the low limit value shall be set to 1300 V and the very low limit value shall be set to 1100 V in accordance with the requirements of T HR EL 90002 ST. Both the low limit and the very low limit shall have a delay of 10 s.

e. 1500 V dc voltage analogues and feeder current analogues in operation

The analogue limit value shall not be changed by ESOs alone. Advice shall be sought from the Sydney Trains' Electrical Network Manager when it is necessary to change the values. Any configuration change shall be noted on the SCADA system if capability exists, or in a network configuration document. The operational requirements for 1500 V dc analogues are as follows:

i. Operation of 1500 V dc feeder currents

The ESO is not required to act on 1500 V dc feeder current limit digressions as there will be no alarm. An event will be generated and it will be necessary for a protection engineer to analyse the event list regularly to identify DCCBs that may require settings to be modified.

ii. Operation of 1500 V dc voltages

If the high limit alarm occurs during standard timetable operating conditions, determine if the value is in a steady state from an unusual short term operating arrangement (less than 300 s – this is due to both the surge arrestor rating and the requirements of T HR EL 90002 ST) or if the value is steadily increasing. If the value is in a short term steady state because of operating arrangements, then it should return to normal limits when the unusual operating arrangements come to an end. If the value is steadily increasing and the very high limit is reached, then with the agreement of the Sydney Trains' Electrical Network Manager, trains in the sections affected should be stopped at the nearest station and the circuit de-energised.

For conditions other than standard timetable conditions (such as during maintenance), it is acceptable for the voltage to rise above the high limit value. When the very high limit alarm occurs, the voltage should be monitored. When the value remains above the very high limit for greater than 300 s, then with the agreement of the Sydney Trains' Electrical Network Manager, trains in the sections affected should be asked to stop at the nearest station and the circuit de-energised.

The highest value that the SCADA system can read is the engineering maximum, which is typically 2200 V.

Commissioning analogue voltages and currents

When commissioning analogue values, each alarm value configured on the master station shall be checked to confirm that the configuration setting is correct. To test the scaling of the analogue point, simulate the output of the transducer by using a portable 10 mA or 20 mA current source (depending on the transducer output) connected across the RTU's analogue input resistor.

The commissioning of a SCADA analogue shall be documented according to T HR EL 11001 PR and stored in accordance with T HR EL 99001 ST.

For further information about analogue alarm history and the alarm delay function, see Appendix E.

6.3. Digital inputs

All positions of an input shall be tested (for example, high or low, alarm or normal, open or closed, rail or earth position and all tap positions).

All protection alarms shall be generated from the protection relays.

Digital inputs shall be wired in a fail-safe contact arrangement (a voltage present at the RTU when the indication is in the normal state). Exceptions may exist for some equipment which are listed in T HR EL 11001 TI.

6.3.1. Digital input alarms

Digital inputs shall only alarm if it is required that operators perform an action as stated in the operating instruction for that equipment.

6.3.2. On the master station

When commissioning alarms, check for correct entries in various lists (for example, alarm, maintenance, event and abnormal lists), check that alarms alert ESOs to the correct HMI display and check for the audible alarm.

ACCBs with the auto reclose feature should be tested if the operating diagram shows this protection function.

6.4. Digital outputs (controls)

The actual equipment shall be operated in all positions. If this is not possible, then a simulated test shall be performed and noted on the test record.

Appendix A DC current circuit information for older DCCBs with U-MLEs relays

The Microelettrica Scientifica U-MLEs dc feeder protection relay, which replaces delta I relays or is used for dc inter-trip, is installed in the current analogue circuit with the ammeter and SCADA RTU analogue input. This appendix contains information about the circuit.

A.1. Circuit description

The circuit consists of a dc feeder, shunt, potentiometer, transducer, ammeter and SCADA analogue with associated wiring.

A.1.1 Shunt

The shunt is in series with the dc feeder and produces a voltage proportional to the current flowing through the feeder. The shunt ratio at the majority of locations is ±4000 A/±50 mV. Other ratios such as ±4000 A/±150 mV are used at some locations. See Figure 2 for an example of a shunt.

A.1.2 Potentiometer

The potentiometer is used at some locations to adjust the output of the shunt. They are generally located at power supply upgrade project locations and change a 50 mV shunt output to 45 mV.

A.1.3 Transducer

The transducer may be a Secheron MIU6 or MIU10 depending on the age of the location.

- The MIU6 has three selectable input levels (±60 mV, ±90 mV, ±150 mV) and nominal output currents of ±5 mA or ±20 mA. The power supply is 17 V dc to 140 V dc.
- The MIU10 has five selectable current input levels (±60 mV, ±90 mV, ±150 mV, ±300 mV, ±500 mV) and an output current of ±20 mA dc. The power supply is 24 V dc to 230 V dc.
- At Yennora (and other locations), the MIU6 input is set to ±90 mV, the output to ±20 mA.

A.1.4 Ammeter

Ammeters are similar at all locations, that is, ±20 mA input and ±8 kA display reading.

A.1.5 Wiring

The wiring between the DCCB and RTU is shielded. The shield is terminated at the trunk connection for the ammeter to trunk section and at the RTU for the trunk to RTU section.

A.1.6 RTU

The RTU analogue inputs are actually voltage inputs, so a resistor is used to convert the current loop to a voltage. Different RTUs have their own resistor and voltage input values. The following list contains an indication of RTU type and resistor value to produce full-scale voltage from 20 mA.

- Invensys or Foxboro SCD5200 – 100 ohm resistor for 2 V
- Invensys or Foxboro C50 – 50 ohm resistor for 1 V
- Logica MD1000 – 500 ohm resistor for 10 V
- Logica MD3311 – 500 ohm resistor for 10 V
- Kingfisher Series 2 – 250 ohm resistor for 5 V

A.1.7 Protection relay

The Microelettrica Scientifica U-MLEs is added to the current loop circuit. It has a wide ranging power supply of 90 V dc to 250 V dc ±20%.

A.1.8 Accuracy

MIU6 transducer has an output error of ±0.5%. The MIU10 output error is ±0.1%.

The RTU (with a precision resistor and analogue to digital converter) has an error of 0.25%.

The U-MLEs relay has a measured accuracy error of ±1%.

A.1.9 Loading

The MIU6 transducer has a maximum loading on the output of 425 ohm and the MIU10 transducer has a maximum loading on the output of 600 ohm. This affects the number and types of equipment that can be placed in the circuit. The loads on the current loop circuit include the ammeter, RTU and the UML relay, which are as follows:

- the ammeter's load on the circuit is 50 ohm
- the RTU's input resistance is between 50 ohm and 500 ohm depending on the type of RTU
- the Microelettrica Scientifica U-MLEs operational manual does not give values for the input resistance to determine the full load on the current loop circuit

To avoid failures, an MIU6 transducer should be replaced with a MIU10 for a Logica RTU.

A.1.10 Circuit security

Adding a protection relay to this circuit changes the security and reliability requirements for all devices on the circuit. Therefore, only suitably trained and accredited staff may perform work on this circuit.

A.1.11 Failure modes

Being resistive, the most likely failure mode of the potentiometer, ammeter and RTU resistor is open circuit. A short circuit failure occurs in less than 10% of failures.

The failure mode of the transducer is that there will be no output when the power supply fails. If there is a failure of the input or output circuit then they are likely to short circuit as there are Zener diodes. The isolation of the transducers, for reference, is as follows:

- MIU6's isolation between output and power supply is 2 kV
- MIU10's isolation between output and power supply is 4 kV

A.1.12 Integrated test plan

The following is the suggested test plan to be completed. Before starting preparation and inspection, confirm the following:

- the shunt ratio (inspect the shunt), most shunts are 4000 A/50 mV
- the ammeter resistance
- the existence of a potentiometer
- the type of transducer – MIU6 or MIU10
- the type of RTU
- the location of the analogue input on the RTU (advised by the operator's SCADA engineering section)

Equipment required includes a voltage source and a multimeter.

A.1.12.1 Steps

The following steps are to be followed when completing the integrated test plan:

1. simulate the shunt by applying 50 mV dc to the potentiometer or 45 mV dc to the input of the transducer
2. the output of the potentiometer (if it is installed) should be 45 mV dc
3. the output of the transducer should be 10 mA

4. the voltage at the input to the RTU should be 1 V dc, 2 V dc, 5 V dc, or 10 V dc depending on the RTU
5. with correct scaling on the master station, the value should be 4000 A
6. the value displayed on the protection relay should be 4000 A ±1.5% (+ shunt accuracy)

A.2. Photos

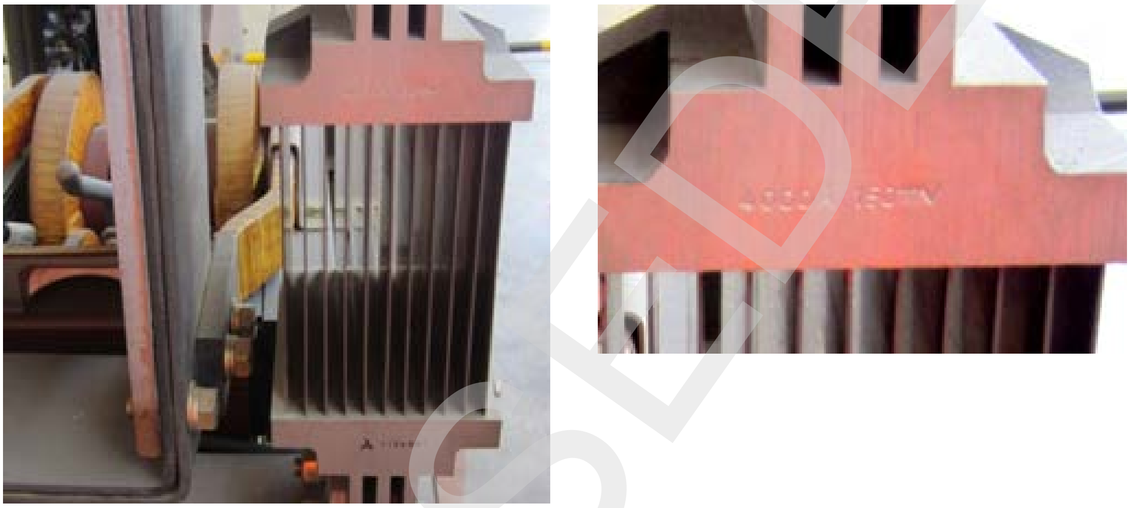

Figure 2 - Shunt with ratio

Appendix B Sample master station commissioning form

The following is an example of the form to be used by the maintainer when transferring the responsibility of equipment on the SCADA system between the operator's SCADA engineering section and electrical operating centre.

Location

XYZ substation

Expected date in service

7-9 July 2016

Equipment being commissioned

All 33 kV ACCBs including 700, 701, 702 and associated equipment have been tested, with the SCADA equipment where possible, and are ready for service. Any exceptions are noted in SCADA exceptions following.

SCADA exceptions

The following indications are exceptions. They are either not ready for commissioning or will be in the alarm state until commissioning occurs.

Location	Date in service	Equipment	Indication still future	Reason	Responsibility

Location	Date in service	Equipment	Indication in alarm state	Reason

ESO comments

Location	Equipment	Indication	Comments

After commissioning, return this form to the SCADA engineering section to complete the commissioning records.

Appendix C Future strategies

Appendix C.1 contains future SCADA strategies.

C.1. Substation RTU local software routines

RTUs are capable of performing tasks automatically using software routines. One advantage of doing this is that when the master station communications have failed, or the master station has a software or hardware issue, then the RTU can continue to perform tasks autonomously.

C.1.1 Staff alarm

The RTU monitors whether staff are present at the location by monitoring door reed switches and staff switches. It also controls a buzzer to provide an alarm on entry. This functionality is useful for security monitoring and providing ESOs with an indication of the position of staff.

C.1.2 Auto-reclose

DCCBs have the auto-reclose functionality onboard. However, for ACCBs, the master station sends an auto-reclose control to the ACCBs that are enabled to do so. This is disabled by an ESO action at the master station either on an individual ACCB basis or for all 'fire-ban' ACCBs (see Appendix C.1.3 for more information on fire-ban ACCBs). This function could be performed by the RTU and disabled by a control from the master station.

C.1.3 Fire-ban

Auto-reclose of ACCBs is performed by the master station. Activating the fire-ban inhibits any auto-reclose sent by the master station. This function could be moved to the RTU and be disabled by the master station when necessary. A disadvantage of this application is that ESOs would not know whether the RTU or a local operator performed the action.

C.1.4 Control inhibit

The master station limits the times when auto-reclose controls can be performed. The auto-reclose control is usually inhibited for ten minutes after the following:

- when a control has failed to be sent from the master station
- when the RTU has been put back into scan or had communication problems
- after the master station has restarted

This could be moved to the RTU, but some functionality would be lost.

C.1.5 Harmonic filters

If the harmonic filter circuit breaker is closed too soon after opening, an unsafe voltage could develop across the capacitor bank if they have not discharged. To prevent this, there is a timer on the switchgear that inhibits local and remote control for ten minutes after the circuit breaker opens for any reason. However, someone could reduce the time by rotating a dial on the timer. Therefore, a ten minute remote control inhibit on the SCADA RTU adds an extra layer of protection for staff and equipment. This starts when the circuit breaker has opened.

C.1.6 Calculations

Calculations could be performed by the RTU such as total substation load (divided into traction and non-traction) and 30 min rms values for ac currents.

Appendix D Diagrams

Appendix D.1 to Appendix D.5 contain wiring diagrams for the electrical SCADA interface.

D.1. Digital input wiring

Figure 3 illustrates the wiring requirements for digital inputs.

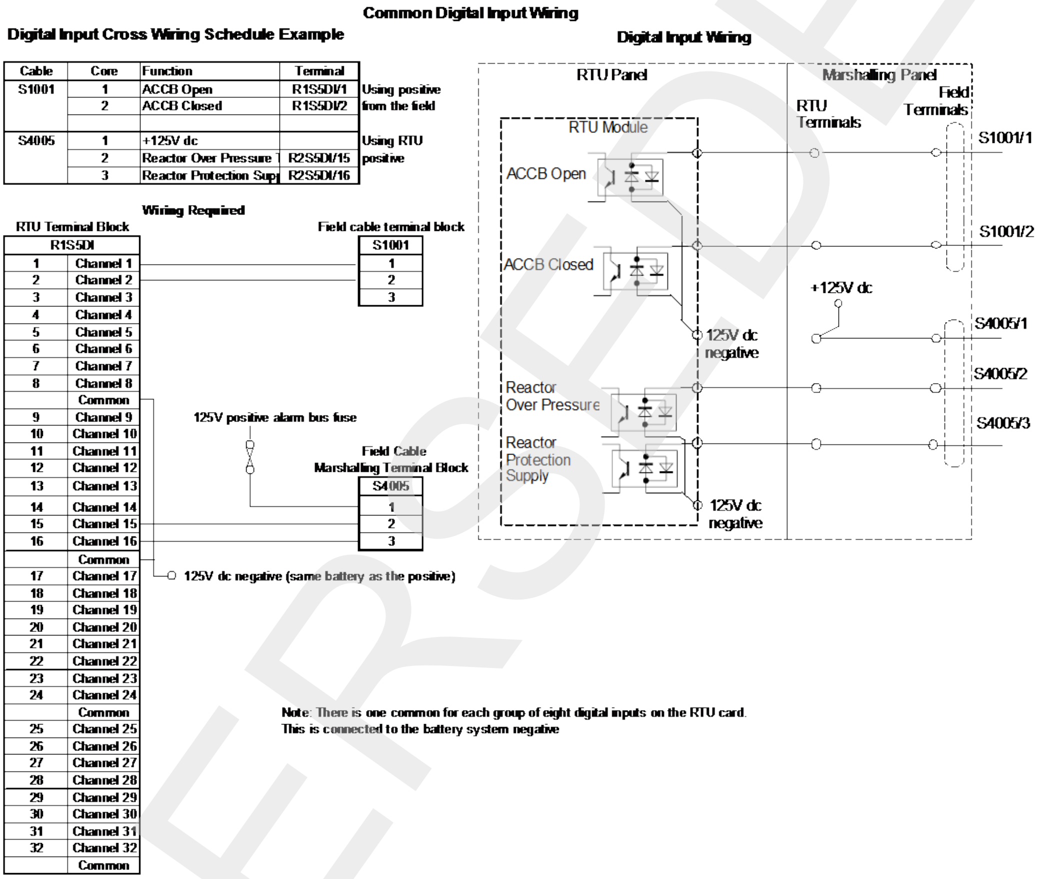

Figure 3 - Digital input wiring

D.2. Analogue input wiring

Figure 4 illustrates the wiring requirements for analogue inputs.

Analogue Input Cross Wiring Schedule Example

Cable	Core	Function	Terminal
IA210	W	B ph Current	R1S5AI/36+
	BLK	-ve	R1S5AI/36-
	SCR	Screen	

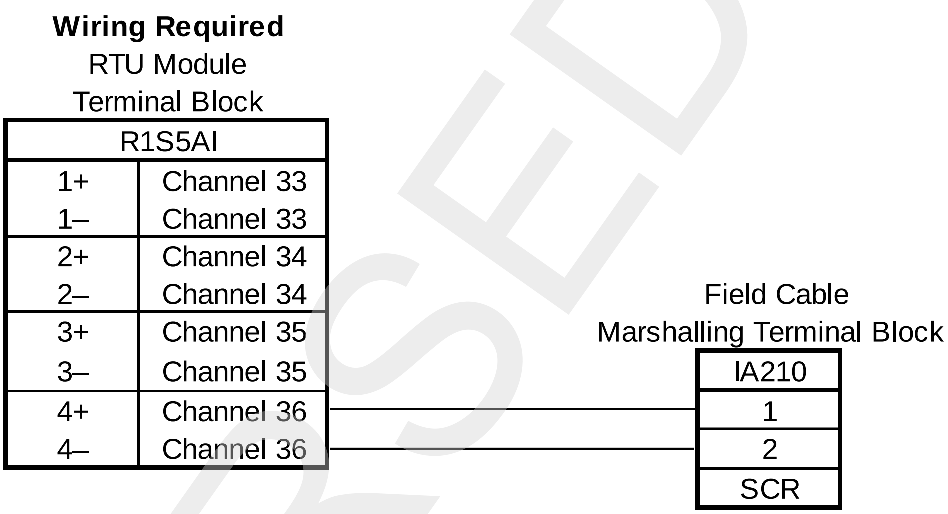

Figure 4 - Analogue input wiring

D.3. Control wiring

Most equipment use two-wire controls as illustrated in Figure 5.

CONTROL WIRING

Cross Wiring Schedule Example

Cable	Core	Function	Terminal
S133	1	125V +ve	R1S9DO/2-a
	2	Remote Close	R1S9DO/2-b
	3	125V +ve	R1S9DO/1-a
	4	Remote Open	R1S9DO/1-b

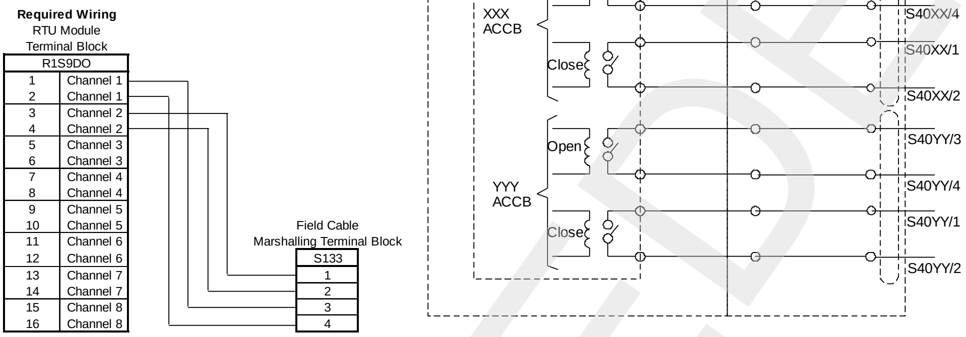

Figure 5 - Control wiring

D.4. Standard communication wiring

Standard communication wiring involves 48 V dc supplies and fibre cable layout. See also MET RL 0363 *Communications Cabinet for HV Locations – Typical Arrangements.*

The following materials are required (the numbering corresponds to the numbers in Figure 6):

1. three off multi-mode optical fibre (MMOF) patch leads SC to SC, length as required (with 3 m spare), for MMOF patch panel (RTU cabinet) to MMOF patch panel (comms cabinet)
2. two off MMOF patch leads ST to SC, 62.5 µm or 125 µm, 2 metres, for media converter to MMOF patch panel (communications cabinet)
3. two off category 5 (CAT5) patch leads for media converters to communications switches (communications cabinet)
4. two off MMOF patch leads ST to SC, 62.5 µm or 125 µm, 2 metres, for MMOF patch panel to RTU (RTU cabinet)
5. two off MMOF patch panels – 1 rack unit (1 RU) high, rack mount, 24 way panel

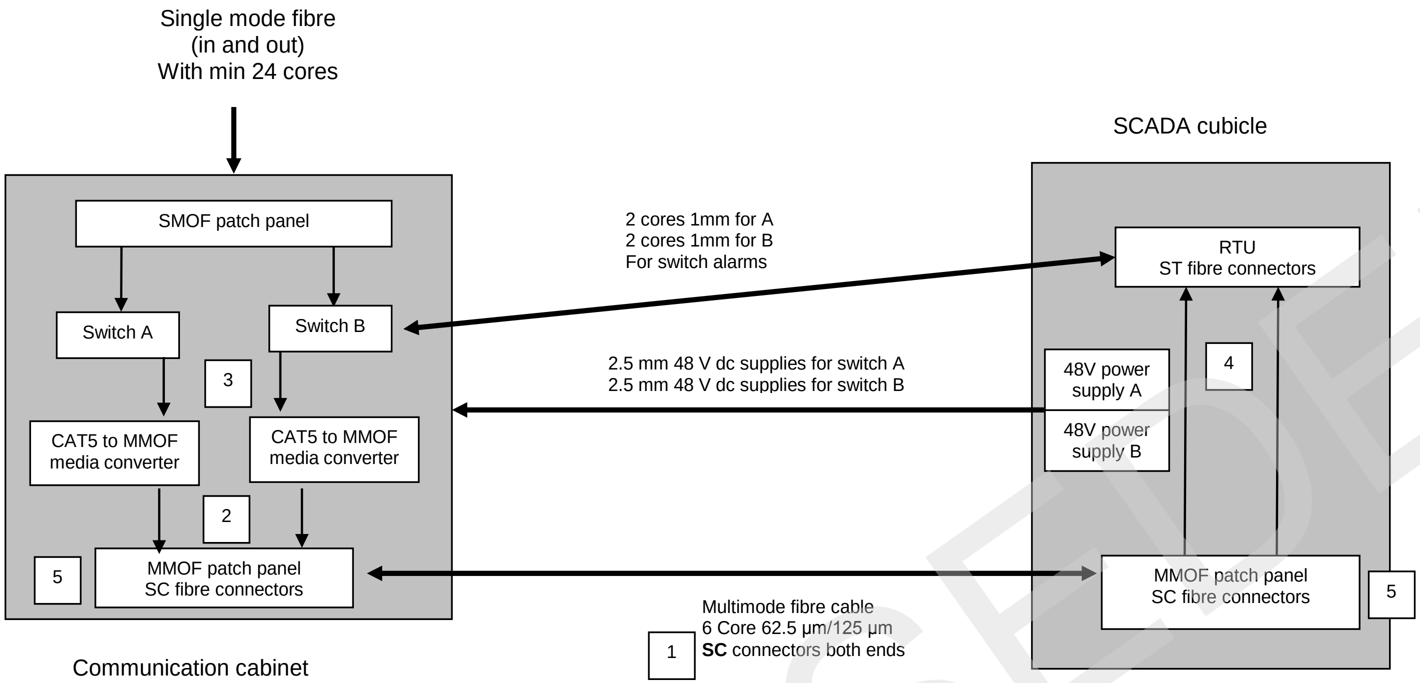

Figure 6 - Standard communication wiring

D.5. Slave RTU communication wiring example

Figure 7 shows an example of slave RTU communication wiring, in a layout of a pumping station.

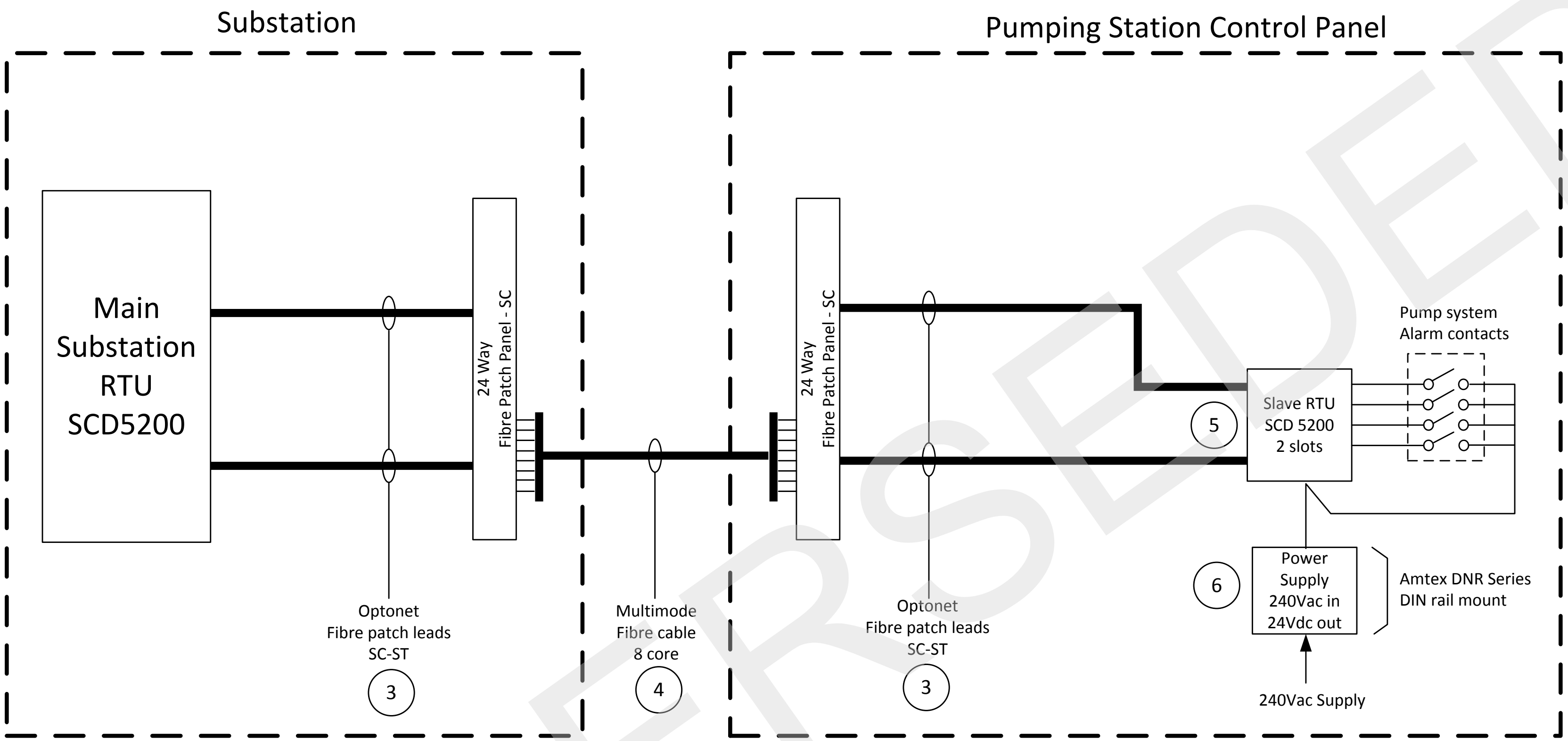

Figure 7 - Example of a pumping station layout

Appendix E Analogue alarms

Appendix E.1 to Appendix E.2 contain background information for the setting of analogue alarm limits.

E.1. Examples of analogue alarm history

The following list gives background information about the number of analogue alarms received and the reason for choosing certain values. It also shows how the new settings are expected to affect the number of alarms received:

a. 1500 V dc feeder currents

From 14 January 2015 to 16 July 2015 there were 1208 alarms from 1500 V dc feeder current analogues, going above the alarm limit and returning to normal. Most alarms were from Gordon and the feeder current analogues were prevented from alarming. The current went over 4000 A 36 times (all from Gordon). It was between 3000 A and 4000 A 436 times (mostly from Gordon).

With the new configuration settings, there would be no alarms.

b. 1500 V dc voltages

From 11 June 2014 to 11 June 2015, there were over 17,000 alarms from 1500 V dc voltage analogues (high, critical high and their return to normal). During this time, the 1500 V dc voltage went between 1950 V and 2000 V nine times, between 2000 V and 2050 V four times and over 2050 V five times. For all of these occasions, maintenance work was being performed at the locations.

With the new configuration settings, there would have been only 10 alarms instead of the 17,000.

c. HV ac feeder currents

This is an example of information currently available about Strathfield 715 current from various sources for choosing a method of comparing SCADA data with the feeder rating.

From the feeder data book, the continuous feeder rating is 390 A (the lowest rating of cable sections, transmission line sections and the current transformer (CT)).

The power study maximum load (2013 timetable) is 520 A (2 s rms) and 300 A (30 min rms). These values from the power study provide a calculated maximum load for the feeder for the busiest time, which is between 08:00 am and 08:30 am on a weekday and are not linked to the actual rating of the feeder and equipment.

On the SCADA master station, the analogue alarm limits are set to 350 A for the high limit and 400 A for the very high limit. According to this standard, the high limit would be set to

390 A and the very high limit would be set to 800 A (double the CT ratio). On 20 August 2014, during abnormal feeding with 721 open, the maximum values were 410 A (1 s rms), 254 A (5 min rms), 227 A (30 min rms). The value was over the limit for two or more samples one out of eight times (only two consecutive samples were over the limit for a total of three seconds). On 17 January 2014, with normal feeding, the maximum values were 320 A (1 s rms) and 190 A (30 minute rms).

E.2. Alarm delay function description

The master station's alarm delay function prevents the high limit from alarming for a period of time. This means that the master station will only generate an alarm if the analogue value stays above the high limit for the delay time. Therefore, if the delay time is set to 10 s, the analogue value needs to stay above the high limit for more than 10 s for the alarm to be generated. If the value returns to normal in less than 10 s, no alarm will be generated and the delay timer will be reset.

The master station currently scans analogue values every 5 s, so a delay of 10 s means that the analogue value needs to remain above the limit for more than one sample before alarming. This avoids a momentary fluctuation in current or voltage from causing an alarm.