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Electrical

Title
33kV AC Indoor Switchgear – Non-Withdrawable

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About This Standard

This document details the whole of life performance requirements for indoor 33kV non-withdrawable switchgear for use in the ARTC traction system. All information required to ensure that the switchgear is electrically suitable for the ARTC network is contained in this document or referenced by this document.

Switchboard Units of three, four and five SCADA controlled circuit breaker panels are combined in units and arranged in linear or ring bus configurations. Where a busbar is to be divided into two or more sections each section will comprise of a separate switchboard unit, physically separated from the other unit(s) and connected by a tie cable through a bus sectioning circuit breaker at each end of the tie cable.

Only circuit breakers panels are included. Specific circuit breaker panel configuration requirements are set out for the following applications: feeder, bus tie, rectifier transformer, system transformer. The protection equipment is located immediately above the relevant circuit breaker. Specific details of the required protection schemes are not included here and are specified in *PDS 09 – Protection System Requirements for the High Voltage Network.*

Document History

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List of Amendments –

ISSUE	DATE	CLAUSE	DESCRIPTION
1.1	05/01/2005		Reformatted to ARTC Standard
1.2	11/03/2005	Disclaimer	Minor editorial change

Contents

1 Scope and Application

1.1 General

This document specifies the characteristics of factory assembled, non-withdrawable switchgear designed for indoor installation on ARTC sub-transmission systems operating at nominal 33kV a.c., three-phase, 50 Hz. The requirement is for Switchboards of three, four and five SCADA controlled circuit breaker panels suitable for deployment in linear or ring bus configurations. Where a busbar is to be divided into two or more sections each section will comprise a separate Switchboard Unit, physically separated from the other unit(s) and connected by a tie cable through a tie circuit breaker at each end of the tie cable. Only circuit breakers are included. Specific circuit breaker panel configuration requirements are set out for the following applications:

- feeder,
- bus (switchboard) tie,
- rectifier transformer,
- system transformer.

The switchgear panels will in general each include equipment that comprises a fixed circuit-breaker, with an associated off-load disconnector and earthing facility, in combination with the associated control, measuring, indicating, alarm, and protective equipment, including interconnections, accessories, enclosures and supporting structure.

The protection and control equipment is located in or immediately above the relevant circuit breaker panel. Details of the required protection schemes are specified in ARTC standard *PDS 09 – Protection System Requirements for the High Voltage Network.* The switchboard shall incorporate the applicable requirements of *PDS 09.*

Specific details for the rectifier transformer circuit breaker protection and control are to be in accordance with RailCorp publication *EP 03 02 00 01 SP – Controls & Protection for Rectification Equipment.*

Busbar voltage transformers are required for all switchboard units.
In the event of major failure it is anticipated that the entire switchboard unit would be replaced rather than attempting on-site replacement of a single panel.

The switchgear is intended for indoor use under ambient conditions as specified in ARTC standard *PDS 11.*

1.2 Application

The requirements of this document apply when a new 33kV indoor switchboard is installed in a ARTC substation.

The requirements of this document are not applicable to existing 33kV indoor switchboards currently in service in the ARTC network.

2 Reference Standards

The following documents contain provisions that, through reference in this text, constitute provisions of this specification.

At the time of publication, the editions indicated below were valid.

2.1 International Standards

IEC 61958, 2000	High-voltage prefabricated switchgear and control gear assemblies - Voltage presence indicating systems
IEC 62063, 1999	High-voltage switchgear and control gear - The use of electronic and associated technologies in auxiliary equipment of switchgear and control gear
IEC 62271–100, 2003	High-voltage switchgear and control gear - Part 100: High-voltage alternating-current circuit-breakers
IEC 62271–102, 2001	High-voltage switchgear and control gear - Part 102: Alternating current disconnectors and earthing switches
I EC 62271–200, 2003	High-voltage switchgear and control gear - Part 200: A.C. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
I EC 60051-1, 1997	Direct acting indicationg analogue electrical measuring instruments and their accessories Part 1: Definitions and general requirement common to all parts
I EC 60051-2, 1984	Direct acting indicationg analogue electrical measuring instruments and their accessories Part 2: Special requirements for ammeters and voltmeters
I EC 60051-3, 1984	Direct acting indicationg analogue electrical measuring instruments and their accessories Part 3: Special requirements for wattmeters and varmeters
IEC 60051-7, 1984	Direct acting indicationg analogue electrical measuring instruments and their accessories Part 7: Special requirements for multifunction instruments

2.2 Australian Standards

AS 1265–1990	Bushings for Alternating Voltages above 1000V.
AS 1852.441-1985	International Electrotechnical Vocabulary. Chapter 441: Switchgear, control gear and fuses
AS 1939-1990	Degrees of Protection Provided by Enclosures for Electrical Equipment (IP Code).
AS 2067-1984	Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV

AS 2650-2000	Common specifications for high-voltage switchgear and control gear standards
AS 2700-1996	Colour Standards for General Purposes.
AS 60044.1-2002	Instrument transformers - Current Transformers.
AS 60044.2-2003	Instrument transformers - Voltage transformers
AS 60265-2001	High-voltage switches - Switches for rated voltages above 1 kV and less than 52 kV
AS 3760-2001	In service Safety inspection & testing of electrical equipment.

2.3 ARTC Standards

Key ARTC Standards:

Several significant sets of requirements applicable to 33kV AC Indoor Switchgear (non withdrawable) are common to other classes of equipment and are set out in the following ARTC standards. The equipment shall comply with the relevant requirements set out therein.

POP 01	Electrical Power Equipment - Integrated Support Requirements
PDS 12	Common Requirements for Electric Power Equipment
EP 03 02 00 01 SP	Controls & Protection for Rectification Equipment (RailCorp publication)
PDS 09	Protection System Requirements for the High Voltage Network

Other ARTC Standards:

PDS 11	Electrical Power Equipment - Design Ranges of Ambient Conditions
PDS 17	Insulation Coordination and Surge Arrester Selection
PCS 05	Standard Voltage Tolerances

3 Definitions, Terms and Abbreviated Terms

3.1 Definitions and Terms

For the purpose of this specification, the terms, definitions and abbreviated terms in AS 1852.441 and the following apply:

Circuit-breaker
a mechanical switching device that is capable of making, carrying and breaking currents under normal circuit conditions, and also of making, carrying for a specified time and breaking currents under specified abnormal conditions, such as those of a short-circuit.

Circuit-breaker panel
a switchgear panel complete with a fixed circuit-breaker, switch-disconnector, earthing switch and protection & control equipment.

Earthing switch
as defined in (AS 1852(441) 441-14-11).

Fixed circuit-breaker
a circuit-breaker which is not a withdrawable part of the panel assembly it which it is mounted.

Metal-clad switchgear
metal-enclosed switchgear in which certain components, for example, circuit-breakers, are arranged in separate compartments that have metal partitions and that are intended to be earthed.

Non-withdrawable switchgear
switchgear that contains circuit-breaker and switches, which are not a withdrawable part of the panel assembly in which they are mounted.

Rated insulation level
the combination of the rated lightning impulse withstand voltage and the rated short duration power frequency withstand voltage specified in AS 2650.

Rated normal current
for main circuits and switching devices, the r.m.s. value of the current that they are designed to carry continuously under the specified conditions of use and behaviour.

Rated peak withstand current
for main and earthing circuits, the peak current associated with the first major loop of the short-time withstand current that a mechanical switching device is designed to carry in the closed position under prescribed conditions of use and behaviour.

Rated short-time withstand current
for main and earthing circuits, the r.m.s. value of current that the switching device is designed to carry in the closed position during a specified short time under prescribed conditions of use and behaviour.

Rated voltage
the highest r.m.s. phase-to-phase voltage of the supply on which the switchgear is designed to operate.

Switch
a mechanical switching device that is capable of making, carrying and breaking currents under normal circuit conditions, which can include specified operating overload conditions, and also capable of carrying for a specified time, currents under specified abnormal circuit conditions such as those of a short-circuit.

Switchboard
two or more switchgear panels coupled together in various combinations.

Switch-disconnector
as defined in AS 1852(441) 441-14-12.

Switchgear
a general term that covers switching devices and their combination with associated control, measuring, indicating, alarm, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended, in principle, for use in connection with the generation, transmission, distribution and conversion of electric energy.

Switchgear panel (or panel)
switchgear of modular design that comprises a mechanical switching device, for example, a circuit breaker, a switch-disconnector, a switch-fuse combination or a switch.

Withdrawable
as defined in AS 1852(441) 441-13-09.

3.2 Abbreviated terms:

ARTC
Australian Rail Track Corporation

CT
Current Transformer

VT
Voltage Transformer

4 Background

ARTC operates a high voltage AC network in which the nominal voltages used are 11 kV, 33kV, 66kV and 132kV. ARTC also operates a 1500V DC network that supplies power for electric traction. The majority of ARTC substations are traction substations where transformers and rectifiers convert the high voltage AC supply (33kV or 66kV) to 1500V DC.

The majority of the existing 33kV traction substations have outdoor 33kV switchyards comprising circuit breakers, air-break switches, instrument transformers and busbars along with the rectifier transformers and system transformers. Protection and control equipment is located inside the associated substation building.

Other 33kV traction substations have an indoor 33kV switchboard(s), which comprise of the 33kV busbar, 33kV circuit-breakers, cable boxes and protection and control equipment.

An indoor 33kV switchboard is the preferred method for the protection and control of the 33kV network.

5 Functional Characteristics

The 33kV indoor switchgear covered by this standard shall:

- Provide a 33kV busbar and busbar voltage transformer.
- Provide for connection of 33kV feeders, bus tie cables, rectifier and power transformer circuits to the 33kV busbar.
- Provide for isolation and earthing of feeders, bus tie cables, rectifier and power transformer circuits.
- Provide protection and control for 33kV feeders, rectifier and power transformer circuits and sections on the 33kV busbar.
- Provide the means to perform a DC cable test on the HV cables, without disturbing existing HV cable connections.

Note: There is no requirement to provide a facility to earth the busbar.

6 Performance Characteristics

6.1 General

The switchboard shall be designed and manufactured in accordance with following standards:

- AS 2067,
- AS 2650 and
- IEC 62271 – 200,

Except where specifically varied in this standard.

It shall have the following characteristics:

Number of Phases	3
Nominal System Voltage	33kV non effectively earthed
Type	Metal Clad
Installed	Indoors
Insulation	Air, cast resin, or SF_6
Circuit-breakers	Non withdrawable
Busbar	Single

Table 1 – Switchgear characteristics

The switchboard shall be suitable for the environmental conditions as described in ARTC standard: *PDS 11, Electrical Power Equipment - Design Ranges of Ambient Conditions .*

Similar components of all equipment shall be capable of being interchanged.

6.2 Switchboard Ratings

The switchgear shall have the following general ratings:

Rating Type	***Rating***
Rated voltage	36 kV
Line to Earth Voltage Rating	Suitable for Resistively Earthed System
Rated frequency	50Hz
Rated Normal Current - Busbar	1250 amps (min)
Rated Normal Current – Feeder and Bus Tie Circuit Breaker Panels (steps as per R10 series defined in IEC 60059)	630 A, 800 A, or 1250 A
Rated Normal Current – Rectifier Transformer Circuit Breaker Panels	630 A
Rated Insulation Level:	
Minimum Rated peak lightning impulse withstand voltage	170kV
Rated short-duration power-frequency withstand r.m.s. voltage	70kV
Rated short-time withstand current Ik	31.5kA
Rated peak withstand current Ip	80kA
Rated duration of short-time current tk	3 second desired (1 sec minimum)
Rated Short Circuit Breaking Current	31.5kA
Rated Short Circuit Making Current	80kA
Rated Operating Sequence	O - 0.3s-CO-3min-CO
Internal Arc Classification (As per IEC 62271-200, Annex A; Defined 3.132)	AFLR Internal arc 25 kA, 1 s

Table 2 – Switchgear Ratings

7 Technical Characteristics

7.1 General

Switchgear shall comply with the requirements of IEC 62271-200, AS 2650.

Specifically, the Switchgear shall meet all Internal Arc Classification (IAC) criteria as proven by test in accordance with Annex A of IEC 62271-200.

7.2 Standard Switchboard Configurations

While a large number of combinations of panels are possible, to simplify logistic support a number of preferred standard configurations have been identified.

The switchgear panels shall be assembled into switchboard units of three, four or five circuit-breaker panels.

Each switchboard unit shall include a bus bar voltage transformer (VT).

The three, four or five circuit-breaker panel switchboards shall be referred to according to the particular circuit-breaker function combination. Standard circuit breaker functions are: Feeders, Rectifiers, System Transformers and Bus-ties.

The functional requirements of each standard circuit breaker are described in the specification *PDS 09, Protection System Requirements for the High Voltage Network.*

The naming conventions for standard switchboard combinations is in accordance with the table below:

Standard Switchboard Configuration Table									
Circuit Breaker Function	**Configuration Type**								
	310	**320**	**410**	**411**	**420**	**421**	**430**	**511**	**521**
Feeders	1	2	1	1	2	2	3	1	2
Rectifiers	1	1	1		1	-	-	1	
System Transformers	-	-	-	1	-	1	-	1	1
Bus Ties	1	-	2	2	1	1	1	2	2

Table 3 – Switchboard configuration type

Figure 1 is an example of a 310 and a 420 switchboard combined in a linear bus via a separate cable. These boards would be physically separated to reduce likelihood of consequential damage to the a neighbouring switchboard in the event of a major switchboard failure.

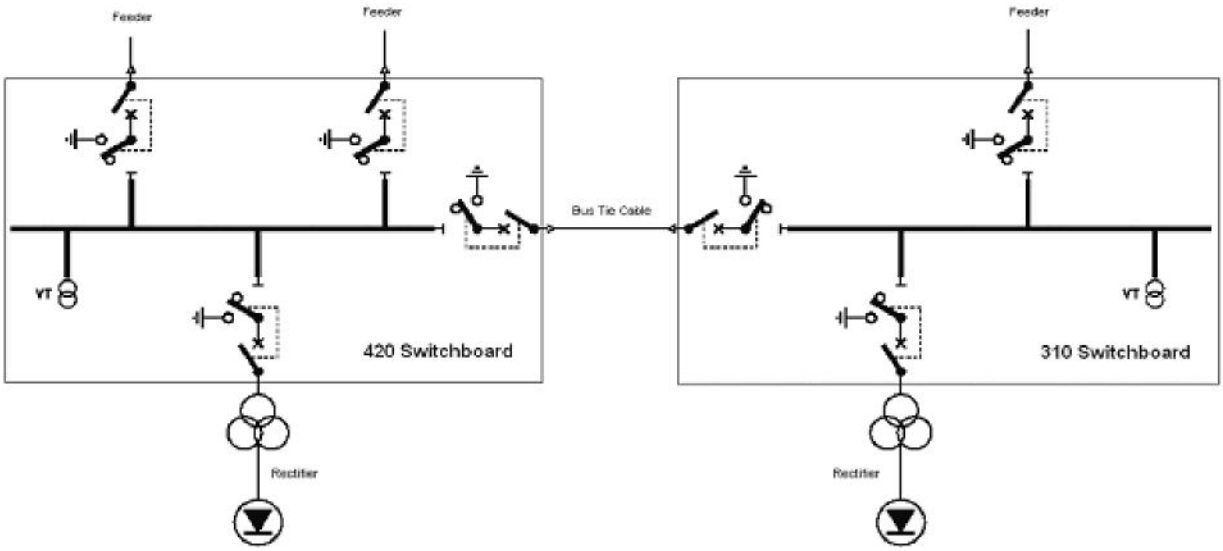

Figure 1 – Example Switchboard configuration

Switchboards with single bus tie panels should have the bus tie at one end of the switchboard. Switchboards with two bus tie panels should have the bus tie panels at opposite ends of the switchboard. Otherwise order is not important.

7.3 Rated Insulation Level

All switchgear of like manufacture shall have the same *Rated Peak Lightning Impulse Withstand Voltage.*

7.4 Control Voltage – DC auxiliary supply voltage

The auxiliary supply voltage shall be 120 V d.c.(nominal).

Auxiliary supply voltage requirements are specified in *PDS 12, Common Requirements for Electric Power Equipment.*

7.5 Busbar

All joints and tees in busbars and busbar connections shall be made with an approved connection type.

If bolts, nuts and washers are used they shall be suitably protected against corrosion in accordance with ISO 9227.

Putty and tape shall not be used.

7.6 Gas insulation (where applicable)

Sulfur-hexafluoride (SF6) insulated switchgear shall be filled with SF6 that complies with the requirements of IEC 60376.

The switchgear shall be factory sealed so as to not require any routine gas replenishment during installation or in normal service.

The design, construction and sealing of gas compartments shall be such that the gas will not require replenishment for 20 years.

It is preferred that switchgear that that requires gassing after panels are assembled in to switchboards be gassed at the factory and transported to site as a single unit.

Only if specifically approved by ARTC, shall gas compartments be assembled, gassed and sealed on site. In this situation the supplier shall test the tightness, in accordance with AS 2650 clause 6.1, and shall certify and warrant for gas tightness.

A device for monitoring the SF6 pressure in each gas compartment while in service shall be provided. This device shall provide indication of the minimum permissible pressure level for safe operation and shall provide two level alarms - level 1 alarm, level 2 alarm and operation inhibit. The pressure level monitoring device shall be clearly visible to the operator from the operating side of the switchgear panel.

7.7 Earthing bar

To assist with stray current mitigation measures from the dc traction system, it may be necessary to connect 33kV cable screens to a separate cable screen earth bar. This arrangement is to facilitate future installation of a transient earth clamp. The transient clamp acts as a DC decoupler, to provide DC isolation between earthing points that are still AC connected. Under an AC earth fault the clamp impedance momentarily changes state to a virtual short circuit, acting to provide a direct connection of HV cable screens to the switchboard earth bar. The transient earth clamp provides a blocking path to dc stray current that could otherwise use the cable screen as a path.

Note some HV panels will require all HV earth screens to be directly connected to the switchboard earth bar.

Each switchgear panel shall include two copper earthing bars, rated for maximum fault levels and not less than 120 mm^2 cross section area to facilitate earthing.

The **cable screen earth bar** shall be connected to the switchboard earth bar via removable links and shall be isolated from similar bars in adjacent panels. It shall be insulated from the frame of the switchboard by insulated mounts that have been rated for maximum earth potential rise and tested for at least 15kV for 1 minute. The cable screen earth bar shall provide for connection of the two removable links, four HV cable screens and mounting holes for a transient earth clamp.

The **switchboard earth bar** shall interconnect adjacent switchgear panels and provide:-

- for all switchgear bonding
- for two cable connections to the main substation earth grid
- for two removable links per panel for connection to the insulated earth screen earthing bar (per panel)
- for connection of four HV cable screens
- mounting holes for a transient earth clamp

To provide for mounting of the transient earth clamp the two earth bars, ie the **switchboard earth bar** and the **cable screen earth bar,** shall be vertically separated as far as possible to provide sufficient space for future insertion of the transient earth clamps.

Earth termination requirements are provided in *PDS 12, Common Requirements for Electric Power Equipment.*

7.8 HV Cable interface

Each circuit-breaker panel shall be equipped with a HV cable compartment providing a dead-break, separable, insulated and shielded system for connection of HV cables. The separable insulated shielded connection system is to be compliant with AS 2629 and relevant ratings specified in table 2, at section 6.2 Switchboard Ratings. At least two single core XLPE insulated 33kV cables per phase of up to 630mm^2 cross section rated for 1250 Amp shall be accommodated.

The cables shall enter the cable compartment from below. The minimum of two cables shall be achieved without sacrificing space for surge arrester equipment. Details of cable connection and restrictions shall be nominated in schedule A.

The cable termination shall be capable of withstanding the power frequency test as specified in Table 1 of AS 2650.

Each circuit breaker panel is to provide the means to perform a DC cable test on the HV cables, without disturbing existing HV cable connections. See clause 7.21 Circuit Test Facilities

7.9 Surge arresters

The switchgear may be installed with short cable feeds.

Sufficient space shall be provided within the cable compartment of each feeder cubicle to install surge diverters if required for the specific feeding configuration.

Surge arrester type and restrictions shall be nominated in Appendix A.

7.10 Current Transformers

The circuit-breaker panels shall be provided with three phase sets of protection current transformers and three phase sets of metering current transformers in compliance with *PDS 09,, Protection System Requirements for the High Voltage Network.*

7.11 Voltage Transformers

7.11.1 General

A three-phase, voltage transformer in compliance with *PDS 09, Protection System Requirements for the High Voltage Network* shall be provided for each switchboard.

For maintenance, and for the commissioning of protection relays, it shall be possible to simulate the voltage conditions that would occur during earth faults and the supplier shall explain how this is achieved (see Appendix A- Technical Schedule,item 49) . A typical way to achieve this is to remove the high-voltage fuse

in any one phase and earth that phase of the voltage transformer.

7.11.2 Directional Protection Supply Alarm

Within each panel the low voltage side of the voltage transformer supply shall be protected by a separate circuit-breaker of adequate breaking capacity complete with voltage free contacts. The main voltage transformer secondary circuit-breaker should discriminate for faults protected by the individual panel circuit-breakers. For each section of the busbar the normally closed auxiliary contacts shall be wired in series to provide a single 'directional protection alarm' in accordance with *PDS 09, Protection System Requirements for the High Voltage Network,* clause 4.6 Protection alarms.

7.11.3 Voltage Transformer Alarm

A three phase, phase failure relay in compliance with *PDS 09, Protection System Requirements for the High Voltage Network* shall be connected to the secondary of the voltage transformer.

7.12 Circuit-breakers

7.12.1 General

Circuit-breaker panels shall comprise of a fixed circuit-breaker, switch-disconnector and earthing switch.

Circuit-breakers shall comply with the requirements of AS 2650 and IEC 62271 – 100.

Circuit-breakers, switch-disconnector and earthing switches that have long mechanical and electrical endurance (as defined in IEC 62271 parts 100 & 102) are preferred.

The protection and control equipment shall be located in or immediately above the relevant circuit breaker panel. Details of the required protection schemes are specified in ARTC standard *PDS 09 – Protection System requirements for the high voltage network.* The switchboard shall incorporate the applicable requirements of *PDS 09.*

Specific details for the rectifier transformer circuit breaker protection and control are to be in accordance with RailCorp publication *EP 03 02 00 01 SP – Controls & Protection for Rectification Equipment.*

7.12.2 Circuit Breaker Type

The interrupting medium shall be either vacuum or SF_6.

7.12.2.1 Vacuum Circuit-Breakers

Means shall be provided for testing the units for loss of vacuum without the necessity of removal of the units.

The contacts of the interrupter shall be held open by a positive fail-safe device independent of interrupter vacuum. The closing arrangement shall be designed so as to give a positive closing action whilst overcoming the contact hold open

device.

7.12.2.2 SF6 Circuit-breakers

Each circuit-breaker shall consist of three separate "pole units" mounted on a single piece frame and shall be mechanically interconnected. The design of the interrupting mechanism and contacts shall be such that the energy dissipated in the SF6 gas is low and does not cause appreciable degradation of gas.

Each pole shall be provided with a separate and independent set of main and arcing contacts to minimise degradation of main contacts during fault interruption. The arcing contacts shall be terminated by tungsten or similar tips and shall be of a high electrical endurance. The main contacts shall be capable of carrying the maximum short circuit current without damage. If butt type arcing contacts are provided, it shall be possible to check the wear of arcing contacts without the necessity to open pole units.

The internal surfaces of all porcelains shall not be glazed.

The circuit-breakers shall be guaranteed to have a leakage rate of less than 1% mass per year of the quantity of SF6 used for filling. Means shall be provided to check the internal pressure of the pole units.

The gas tightness shall be obtained by elimination of any part likely to wear or age.

Certificates and details of tests for tightness carried out on pole units of breakers shall be maintained.

7.12.3 Circuit-breaker operating mechanisms

The circuit-breaker operating mechanism shall be an integral part of the circuit breaker.

Any part of the circuit breaker mechanism that requires routine inspection and maintenance shall not be enclosed in any gas tight compartment.

Solenoid based mechanisms are subject to ARTC approval. A full failure mode and reliability analysis is required for approval.

All circuit-breakers in the closed position shall be able to trip-close-trip before the spring needs to be charged again.

All circuit circuit-breaker panels shall be the XEM type (stored energy operation by means of energy stored in a motor-charged spring with manual or electrical release).

7.12.4 Circuit-breaker Operation and Control

The circuit-breaker closing mechanism shall be electrically operated, trip-free. The circuit-breaker mechanism shall provide lockout preventing closing, as specified in Clause 441-14-23 of AS 1852 (441) – 1985.

Feeder, Bus Tie and System Transformer circuit breakers shall be arranged for operation by local control or by remote supervisory control. The supervisory equipment will provide an open or close command signal of 1.0 A maximum at the

nominated DC control voltage for up to 1.0 second. The control arrangements for rectifiers shall be in accordance with RailCorp publication *EP 03 02 00 01 SP, Controls & Protection for Rectification Equipment.*

The circuit-breaker shall close without delay when the close command signal is applied. While this command signal is applied, the circuit-breaker shall not make a second attempt to close if it fails to close on the first attempt.

The circuit-breaker shall open without delay when the open command signal is applied independently to any of the trip coils or to all trip coils simultaneously.

A mechanical push-button or similar device for tripping the circuit-breaker shall be provided.

Continuously rated control equipment to make the successful closing of the circuit-breaker independent of the length of time that the control switch is held in the CLOSE position and to ensure that only one closing attempt can be made if the control switch is held in the CLOSE position.

7.12.5 Circuit-breaker operation coils

The circuit-breaker shall have one close coil and two trip coils.

All operating coils of the control contactors associated with the solenoid-operated closing device shall be rated for continuous operation.

7.13 Indication

The circuit-breaker panel shall have indication clearly visible from the front of the panel (i.e. either on the circuit-breaker or on the circuit-breaker panel).

The circuit-breaker switchgear panel shall have the following definite indication:

a) circuit-breaker open/close;

b) switch disconnector open/close (if applicable);

c) earth switch position;

d) stored energy device charged/discharged;

e) non-resetable mechanical operation counter.

7.14 Interlocks

Facilities provided for operational access to parts of the switchgear panel that contain live components shall be mechanically interlocked so that access to such parts is not possible unless all live parts have been rendered safe, either by a visibly applied earth connection or by being positively disconnected and screened from the remaining live parts.

Mechanical interlocks shall be provided to ensure positive and substantial protection against malfunction, and shall be so designed and constructed as to ensure dependable fail-safe operation.

Interlocks shall ensure that the disconnector cannot be moved unless the circuit-breaker is open.

Interlocks shall ensure that the circuit breaker cannot be closed unless the disconnector is fully in the “closed”, “isolated” or “earth” position.

Positive mechanical interlocking shall be provided to prevent inadvertent switching from the ON position to the EARTH position without a definite stop in the OFF position, or from the EARTH position to the ON position without a definite stop in the OFF position.

Access to the test terminals shall only be possible when the associated earth switch is in the EARTH position.

When the circuit test facility is in use, it shall not be possible to close the disconnector.

It is preferred that the making of the disconnector contacts in the earth position shall be directly observable by the operator.

If the earthing of a circuit-breaker panel is not visible from the operating position, the corresponding indication shall be directly coupled to the earthing mechanism, to ensure fail-safe indication.

If the switchgear panel is designed so that the circuit to be earthed is earthed through the main contacts of the circuit breaker, then the circuit breaker must be interlocked so that it cannot be tripped by the protection relays or SCADA control while the circuit is earthed.

An analysis shall be provided detailing the integrity of the interlocking system. The analysis shall include all possible failure modes and the controls employed to prevent an unsafe operation.

A table shall be produced of all possible and inhibited states the switchgear may occupy.

7.15 Circuit Earthing Facilities

Each panel shall be equipped with circuit earthing switches manufactured and tested in accordance with IEC 62271-102.

Earth switches shall be the integral type.

The earthing system shall be designed and tested for making a live circuit with a prospective peak fault current of 80 kA. Each circuit earthing switch shall be mechanically interlocked with the corresponding circuit-breaker in accordance with section 7.14 Interlocks of this specification.

The earthing switch shall be rated for fault making if:

- the circuit to be earthed, is earthed through the main contacts of the circuit-breaker, AND
- if there is any identified failure mode which could result in the earth switch being closed onto a live circuit.

Each switch shall be provided with a failsafe indicating device to positively indicate whether it is in the OPEN OR EARTH position and the words "OPEN" and "EARTH" shall be used for the respective indication of these positions.

If the equipment is configured to allow the position of disconnector contact in the earth position to be directly observable, then appropriate illumination shall be provided. The preferred light source is white light emitting diodes. It shall be possible to replace the light source without the need for isolating any HV equipment or significant disassembly of the switchgear.

7.16 Padlocking

Facilities shall be provided to padlock

a) the circuit-breaker in the open positions and the closed position while the disconnector is in the earthed position, and

b) the disconnector in the closed, open and earth positions.

c) the circuit test facility if applicable (see section 7.14 and 7.21) All padlocking facilities shall be suitable for padlocks with a 6mm shank diameter.

7.17 Auxiliary Equipment

Each switchgear panel , with the exception of the rectifier panel, shall be fitted with:

a) A control panel with :

(i) A local CLOSE and OPEN switch or push-buttons coloured red and green respectively.

(ii) LOCAL - SUPERVISORY changeover switch;

(iii) Capability for installation of instrumentation to measure:

- Voltage
- Current
- Energy

The requirement for which instruments are to be installed shall be specified at the time of order.

The requirements of any instrumentation to be fitted, are set out in section 7.18 Instruments, Transducers and Metering- Instruments, transducers and metering

(iv) Live line indicators shall be provided for each of the three phases on each circuit and the busbar. Live line indicators shall comply with the requirements of IEC 61958.

b) Two normally open and two normally closed auxiliary switches rated at 5 amperes in a 120 V d.c. inductive circuit or a 415 V a.c. circuit. (These auxiliary switches shall be provided in addition to those essential to the circuit-breaker operation or provided for already specified functions).

c) A mechanically operated indicator, indelibly marked, to show whether the circuit-breaker is open or closed. The word OPEN shall be visible only if the circuit-breaker is open and the word CLOSED shall be visible only if the circuit-breaker is closed. If colours are used in addition, then the colour green shall indicate the open condition and the colour red shall indicate the closed condition.

d) Electrically operated indicating lights of the LED type.

e) A non-resettable operation counter.

f) A set of terminals for the termination of auxiliary wiring. All auxiliary wiring such as for remote closing and tripping circuits, incoming DC control supplies and all spare auxiliary switches shall be connected to these terminals.

g) Mechanical interlocks shall be provided in compliance with clause 5.11 of IEC 62271-200 to prevent unsafe operation, including:

1) Automatic opening of a circuit-breaker when it is used to earth a circuit or the bus bar

2) Closing of an earthing switch unless the circuit-breaker is in the open position

Each switchboard shall be fitted with a voltmeter to indicate the bus voltage.

7.18 Instruments, Transducers and Metering

7.18.1 General

All instruments, transducers and metering equipment that are required to be fitted shall comply with this section and the relevant requirements in PDS 12, Common Requirements for Electric Power Equipment.

All indicating instruments shall be flush-mounted industrial type instruments that comply with the requirements of the relevant of IEC standards: IEC 60051-1, IEC 60051-2, IEC 60051-3, IEC 60051-7, IEC 60051-8 and IEC 60051-9. The instruments shall be clearly visible and easily readable from a standing position in front of the panel

Scales shall have a scale length of at least 90 mm. All instruments on a switchboard shall be scaled with the same type of characters of the same size.

All current-operated instruments shall be protected against continuous over current up to 120% of nominal value and high current surges up to the fault rating of the circuit-breaker.

7.18.2 Transducers

Current measurements made for SCADA shall use the protection CTs to generate the measurements. Only one current measurement transducer per phase may be interposed between the CT and the protection relay. The approved transducers to be used to measure current are of the 0 – 20mA type and are specified in ARTC standard: PDS 09, Protection System Requirements for the High Voltage Network.

The output of the current transducer shall be used to also drive the ammeter unless the transducer cannot drive both the ammeter and the SCADA measurement circuits. If the ammeter would impose excessive burden on the transducer then separate CTs must be used for metering.

It is preferred that a suitable ammeter should be selected to avoid the need for additional metering CTs.

7.18.3 Ammeters

Ammeters shall have analogue indication with scales that are essentially linear with the scale selected for the instrument accuracy class.

Ammeter scales shall allow for 120% of the primary current rating of the current transformer.

The current transformer ratio shall be clearly marked on the face of the ammeter.

The accuracy of ammeters shall be 3 % or better and shall be stated in the Technical Schedule.

7.18.4 Voltmeters

Voltmeter shall have analogue indication with scales that have an indicating range of 80 % to 120 % of the nominal system voltages.

Where voltmeters that have a nominal range from 0 % to 120 % are required, this will be specified at time of order.

The nominal voltage shall be marked in red on the scale.

7.18.5 Watthour meter

kWh meters shall be three phase, with pulse output. The pulse output rate shall be10 per kWh. Where required for revenue metering the kWh meter is to be connected to a metering CT of suitable rating and accuracy class.

7.19 Busbar and Circuit Protection

7.19.1 General

Protection schemes shall be in accordance with ARTC specification *PDS 09, Protection System Requirements for the High Voltage Network*

7.19.2 Feeder Protection

Primary feeder protection shall be feeder pilot wire.

The feeder protection scheme on incoming feeders shall provide a means of implementing inter-tripping with circuit breakers at the supply end of the feeder where placement of protection CTs leaves a blind spot on the feeder side of the circuit breaker. The inter-trip scheme shall be implemented in accordance with specification *PDS 09, Protection System Requirements for the High Voltage Network.*

If implemented via dedicated inter-trip, then one set of voltage free normally open and normally closed contacts rated to switch 1Amp at 120V dc shall be provided where the feeder can be an incoming feeder. Circuit breakers for feeders that can be arranged as outgoing shall be configured to accept an intertrip signal.

7.19.3 System Transformer Protection

The full set of protection functions required for system transformers including control of the circuit breaker on the other voltage side of the transformer shall be implemented within the 33kV panel.

7.19.4 Rectifier Controls and Protection

The full set of control and protection functions required for rectifiers as set out in RailCorp publication *EP 03 02 00 01 SP - Rectifier Controls and Protection,* including control of the DCCB shall be implemented within the 33kV panel.

7.20 SCADA Indications and Controls

7.20.1 Binary Indications

The following status indications shall be provided to SCADA:

I/O Point Description	Hard Wired	Serial Link
Circuit Breaker Opened & Closed	X	X
Circuit Breaker Faulted	X	X
Trip Circuit OK (trip supply OK)	X	X
Gas/vacuum supervision OK	X	X
Isolator Position (Open, Closed)	X	X
Earthing switch Position	X	X
Protection Relay Faulted	X	☐
Protection relay watch dog Pulse OK	☐	X
Bus Zone Over Current Trip	☐	X
Directional Earth Fault Trip	☐	X
Earth Fault Trip	☐	X
Transformer Differential Trip	☐	X
Bus Zone Trip	☐	X
Frame Leakage Trip	☐	X
Directional Over Current Trip	☐	X
Over Current Trip	☐	X

Table 4 – Binary Indications

7.20.2 Analogue Indication

The following analogue indications shall be provided to SCADA:

- Current (at least 1 phase) for each circuit breaker
- Bus voltage (at least 1 phase) for each switchboard

Current transducers shall be provided to allow monitoring of primary circuit currents by SCADA. They shall be mean-sensing, self-powered AC current transducers. The transducers shall be connected in series with B phase of protection CT circuit or where required by suitable metering CT's. Approved types and details provided in specification *PDS 09, Protection System Requirements for the High Voltage Network.*

7.20.3 Controls

The following control functions from the SCADA system are to be provided for:

- Circuit Breaker Open (trip)
- Circuit Breaker Close

7.21 Circuit Test Facilities

Each circuit-breaker panel shall incorporate an integral type circuit test facility.

All test facilities shall be suitable for the application of d.c. test voltages associated with the after-installation testing of power cables, and shall be rated for the same system voltage as the switchgear.

The test facility shall facilitate the connection of test equipment with the circuit earthed and then allow the earths to be removed with the test equipment still connected.

It shall be possible to connect a hand applied earthing set to the circuit side of each circuit breaker panel for use in conjunction with test equipment. It shall be possible to apply or remove the earth connection independent of the application or removal of the test equipment connection. It is permissible that external removable accessories be used to achieve this function.

8 Integrated System Support Requirements

8.1 Integrated Support Objectives

The switchgear manufacturer must establish and provide the information required to operate and maintain the equipment throughout its operational life, in a cost effective manner and to a level that is consistent with the planned operational performance and usage of the switchgear.

This includes:

- Specifying Maintenance Requirements.
- Spares Support.
- Operations and Maintenance Manuals.
- Training, and
- Support Equipment and Tooling.

8.2 Equipment Supplier Deliverable

The Integrated support requirements are a significant deliverable in the procurement of new Switchgear. Manuals, training, documentation and other support deliverable's shall be in accordance with *POP 01 - Electrical Power Equipment - Integrated Support Requirements.*

9 Tests

Testing requirements are to be read in conjunction with the specification *PDS 12, Common Requirements for Electric Power Equipment.*

9.1 Routine Tests

Routine tests as listed in:

AS 2650, Clause 7

IEC 62271-100, Clause 7

IEC 62271-200, Clause 7

shall be carried out on each panel.

9.2 Type Tests

The results of type tests as required in:

AS 2650

IEC 62271-100

IEC 62271-200

shall be made available by the supplier upon request.

Test certificate details, demonstrating compliance with the above standards, including the date, results and name of the testing body shall be supplied in Appendix A.

Type test certificates for each of these tests will be accepted where it can be demonstrated that the switchgear supplied is of a similar design to previously type tested switchgear.

10 Data Set associated with the Equipment

The following data shall be supplied by the manufacturer and maintained for the switchgear. This data will remain the property of ARTC.

10.1 Information

The information requirements set out in the following standards apply:

POP 01	Electrical Power Equipment - Integrated Support Requirements
PDS 12	Common Requirements for Electric Power Equipment
EP 03 02 00 01 SP	Controls & Protection for Rectification Equipment (RailCorp publication)
PDS 09	Protection System Requirements for the High Voltage Network

10.2 Technical Schedule (Appendix A)

The information listed in the technical schedule of Appendix A, supplied by the manufacturer, shall be maintained for each switchboard.

10.3 Life Cycle Costing

All the data and assumptions pertaining to the determination of the whole-of-life cost calculations shall be recorded.

Appendix A - Technical Schedule

The manufacturer shall supply the information listed in this technical schedule.

Item	Description	Tenderer Supplied Information
1	Switchgear information: a) manufacturer b) country of origin c) catalogue/type designation d) total switchgear mass, kg	
2	Circuit breaker type	SF6 / Vacuum
3	Switchboard - General arrangement drawing showing overall dimensions (h, w, d in mm), cable termination locations and required space around unit for access and arc venting requirements for : Single circuit-breaker panel 3 circuit breaker unit switchboard with bus VT and arc duct (if applicable) 4 circuit breaker unit switchboard with bus VT and arc duct (if applicable) 5 circuit breaker unit switchboard with bus VT and arc duct (if applicable) Required clearances at sides, rear and top of switchboard. Required clearance at front of switchboard for installation and removal Cable trench width	
4	Switchgear Ratings: Voltage, kV Busbar Normal Current, A Insulation Level, kV: Peak lightning impulse withstand voltage, kV	

	Short duration power frequency withstand voltage, kV Short time withstand current (Ik), kA Peak withstand current (Ip), kA Duration of short time current (tk), S Short circuit breaking current, kA Short circuit making current, kA	
5		
6	Ambient conditions assumed for stated current ratings above	
7	Current ratings of switchgear at worst case ambient conditions given in ARTC specification: *PDS 11, Electrical Power Equipment - Design Ranges of Ambient Condition*	
8	Switchgear IEC Classifications: Internal arc classification Internal arc test current, kA Internal arc test duration Circuit breaker mechanical durability class Circuit breaker electrical durability class Switch disconnector mechanical durability class Switch disconnector electrical durability class Earth switch mechanical durability class Earth switch electrical durability class	
9	Details of lifting and slinging for individual panels and 3,4 & 5 unit switchboards	
10	Surge arrestor types accommodated	
11	Surge arrester mounting details / restrictions	
12	Description of panel busbar interconnection arrangements	

13	Description of all operational and safety interlocking arrangements .	
14	Table of all possible and inhibited states that the circuit-breakers and switches in the switchgear may occupy.	
15	Analysis demonstrating the integrity of all interlocking arrangements which includes an analysis of all possible failure modes and the controls designed in to manage them	
16	Auxiliary supply voltage	
17	Is the switchgear self powered?	Yes/No
18	Clearance hole or stud size of earthing bar offered	
19	Gas used for insulation	
20	In which compartments is the gas used?	
21	Detail of gas pressure monitoring device.	
22	Quantity of the SF6 to be used in each separately filled compartment?	
23	Specify the degree of SF6 gas tightness for the switchgear.	
24	If the circuit-breaker is a vacuum type state the method of indicating vacuum loss (if any)	
25	Does the circuit-breaker panel include in-line off-load disconnectors?	
26	Is the switch disconnector offered 2-way or 3-way?	2 or 3
27	Details of the circuit earthing facilities offered including the method of indicating the position of the earthing switch and guaranteeing the integrity of that indication	
28	Diameter of the earthing clamping screw	
29	Supply voltage, peak power and steady power of the springs charge motor (where applicable)	
30	Type of circuit-breaker closing mechanism offered	
31	Rating of each circuit-breaker closing device	

32	Voltage and peak power ratings for the continuous operation of the circuit-breaker coils	
33	Is a solenoid circuit-breaker operating mechanism an option and if so what is its power rating	
34	Number of circuit breaker spare auxiliary contacts	
35	Type of circuit test facility offered	
36	Description of test plugs to be used	
37	Type of switch-disconnector offered	
38	Type of test facility offered	
39	Maximum size and number of HV cables that can be terminated in each circuit-breaker panel. Clearly specify clearances between each cable termination of each phase. Provision of a detailed dimensioned drawing of the arrangement is required.	
40	Type of cable termination offered. Specify manufacturer, model and full details of separable insulated connector. Detail shielding arrangement to be included.	
41	Peak and stand-by power requirements of the switchgear, VA	
42	Type and ratings of live line indicators	
43	CT and VT space limitations and mounting arrangements (for CTs provide details for both bus and circuit sides of the circuit breaker).	
44	Can the busbar VTs be accommodated in circuit-breaker panels?	
45	If busbar VTs cannot be mounted in the circuit breaker panel then describe the mounting arrangement and dimensions	
46	Number and details of the current transformers offered for each function: a) type b) encapsulation material c) class	

	d) burden e) tap ratios f) tap points g) knee-point voltage h) secondary resistance i) excitation current at knee-point voltage	
47	Details of terminal block/rail mounted terminals offered for current transformers.	
48	Type of test block offered	
49	Details of method(s) for simulation of system faults during test & commissioning of directional relays.	
50	----	-----
51	Details of voltage transformers offered: a) name of manufacturer b) withdrawable or non-withdrawable c) ratio d) class e) burden VA f) voltage factor g) location of fuses h) type of fuses i) location of test blocks j) 3 limb or 5 limb k) primary connection at busbar or circuit side	
52		
53	Description of protection equipment	
54	Details of protection equipment offered: a) manufacturer	

	b) type c) rating	
55	Details of points, test burden and current for routine accuracy tests on current and voltage transformers	
56	Details of instruments offered	
57	Details of transducers offered	
58	Details of metering equipment offered	
59	Details of indicators offered	
60	Details of switchgear internal wiring identification	
61	Describe LV termination and cable access arrangements	
62		
63		
64	Rating plate attachment method	
65	Label attachment method	
66	Details of coatings provided	
67	Colours of custom coatings available	
68	Details of serial control interface protocol, if available, on integrated panel and protection control equipment.	
69	**Reliability Data:** Failure Modes (for early, Normal life & wear out periods) Mean Operating Hours between failure modes Mean Time To Repair. Provide details of any special requirements, test and support equipment etc Number of units in service in Australia Number of units in service worldwide	
70	Location of control fuses, mccb;s or links	

Appendix B - RFT Checklist

B.1 Application

The following material is for guidance in the preparation of a Request for Tender for this type of equipment. This checklist itself is not intended to directly form part of any contract.

This section to be read in conjunction with the RFT Checklist in specification *PDS 12, Common Requirements for Electric Power Equipment.*

B.2 Information to be supplied to the Tenderer

Where this document is used as the basis for procurement of equipment for a particular location, in addition to the general requirements in this standard the following information related to the particular site will need to be supplied:

Requirements for specific deliverable's including:

- Installation and on-site operational testing to be carried out by the supplier
- Recovery and replenishment SF6 gas after its service life (must be rendered by the supplier of SF6 switchgear).
- Two spare sets of fuses for each voltage transformer.

Number and type of switchboard configuration selected from table 3 including:

- The continuous current rating of feeder and bus tie circuit breaker panel selected from options in table 2.
- The number of sets and specification of the CTs and protection scheme. Refer to ARTC PDS 09, Protection System Requirements for the High Voltage Network.
- HV cable connection ratings selected from table 2.
- The required number of cables and size per phase, per panel shall be specified at time of order.
- The specific configuration of instruments, transducers and metering equipment (voltage, current and energy), to be installed on switchgear panels shall be specified at the time of order.
- Any required restrictions on the dimensions or placement of the switchgear.
- Location specific surge arrester requirements.
- Notice that the contractor will be required to provide appropriate seals for 33kV receptacles to prevent contamination during storage and transport.
- Notice that the provisionally selected tenderer will be required to provide

access to a sample panel and full set of wiring diagrams for evaluation of the interlocking of the isolate/earth switch by ARTC's interlocking experts (signals discipline).

B.3 Information to be Sought From the Tenderer

- Integrated Support information as per ARTC Standard
- Alternate offers for solenoid based mechanisms.
- Tenders to complete and submit Technical Schedule in Appendix A