## Document control

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Summary of change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>December 2004</td>
<td>Last Technical Review</td>
</tr>
<tr>
<td>3.0</td>
<td>May 2010</td>
<td>Application of TMA 400 format</td>
</tr>
<tr>
<td>3.1</td>
<td>November 2012</td>
<td>Add Appendix C - Requirements for Technical Aspects of Tender Evaluation</td>
</tr>
</tbody>
</table>
# Contents

1. **Introduction** .........................................................................................................................5
2. **References** ..............................................................................................................................5
   2.1 Australian and International Standards ..................................................................................5
   2.2 Drawings ...............................................................................................................................5
   2.3 RailCorp Standards ..............................................................................................................5
3. **Definitions & Abbreviations** ...............................................................................................6
4. **Functional Characteristics** ....................................................................................................7
   4.1 General ..................................................................................................................................7
   4.2 Interchangeability .................................................................................................................8
5. **Performance Characteristics** ................................................................................................8
   5.1 General .................................................................................................................................8
   5.2 Voltage Rating ......................................................................................................................9
   5.3 Current & Short Circuit rating ............................................................................................9
   5.4 Reliability ............................................................................................................................9
   5.5 Multiple Fault Operation .....................................................................................................9
   5.6 Variability of Trip Level .......................................................................................................10
   5.7 Falling Voltage Trip Characteristic .....................................................................................10
   5.8 Current Rate of Rise Characteristic ....................................................................................10
   5.9 Automatic Reclose Undervoltage Characteristic .................................................................11
   5.10 Arc Voltage .......................................................................................................................11
   5.11 Overcurrent Setting ..........................................................................................................11
   5.12 Remote Setting Alteration ................................................................................................11
6. **Technical Characteristics** ..................................................................................................11
   6.1 Mounting of Controls and Auxiliary Equipment .................................................................11
   6.2 Control of Circuit breakers ................................................................................................12
      6.2.1 General .........................................................................................................................12
      6.2.2 BAR Type Circuit Breaker Controls ...............................................................................12
      6.2.3 FAR type Circuit Breaker Controls ...............................................................................12
   6.3 Control Supplies ................................................................................................................13
      6.3.1 General .........................................................................................................................13
      6.3.2 125V Controls ...............................................................................................................13
      6.3.3 1500V Controls ............................................................................................................13
   6.4 Auxiliary Indication Contacts .............................................................................................13
   6.5 Increased Setting Indication Contacts ...............................................................................13
   6.6 Manual Operation ..............................................................................................................14
   6.7 Mechanical Open/Close Indicator .....................................................................................14
   6.8 Local Control and Indication ............................................................................................14
   6.9 Test Button .......................................................................................................................14
   6.10 Arc Chute .........................................................................................................................14
   6.11 Operation Counter ...........................................................................................................14
   6.12 Current Measurement and Indication .............................................................................14
      6.12.1 Ammeter ....................................................................................................................14
      6.12.2 Isolated Current Output .............................................................................................15
6.13 Materials..................................................................................................................................15
6.14 Environment ......................................................................................................................................15
6.15 Noise Emissions.................................................................................................................................15
7 Routine Maintenance Period..................................................................................................................15
8 Integrated System Support Requirements .................................................................................................16
  8.1 Integrated Support Objectives ............................................................................................................16
  8.2 Equipment supplier deliverable.............................................................................................................16
9 Routine Tests .............................................................................................................................................16
  9.1 General..............................................................................................................................................16
  9.2 Dielectric Tests....................................................................................................................................16
    9.2.1 Acceptance Criteria for Dielectric Tests .........................................................................................16
    9.2.2 Main 1500V dc Circuit to Frame .....................................................................................................16
    9.2.3 Across the Main Contacts ...............................................................................................................16
    9.2.4 125V Circuits to Main 1500V dc circuit ............................................................................................17
    9.2.5 125 V Circuits to Frame ...................................................................................................................17
    9.2.6 1500V Control Circuits to Frame .....................................................................................................17
  9.3 Calibration of the Trip Current Value ....................................................................................................17
  9.4 Operation at High and Low Control Voltages .....................................................................................17
10 Type Tests ...............................................................................................................................................18
  10.1 General..............................................................................................................................................18
11 Data Set associated with the Equipment .................................................................................................18
  11.1 Test Results.......................................................................................................................................18
  11.2 Life Cycle Costing.............................................................................................................................18
  11.3 Information to be Provided ..................................................................................................................18
Appendix A Technical Schedule ...................................................................................................................19
Appendix B Request for Tender Checklist ....................................................................................................24
Appendix C Requirements for Technical Aspects of Tender Evaluation .....................................................25
Appendix D RailCorp Standard Type Tests ...................................................................................................26
  Mechanical and Endurance Tests ................................................................................................................26
  Ability to Withstand Short Circuit .............................................................................................................26
  Ability to Withstand Multiple Faults...........................................................................................................27
  Temperature Rise Tests..............................................................................................................................27
  Initial Loading Tests ....................................................................................................................................27
1 Introduction

This document sets out the whole-of-life performance requirements for dc feeder circuit breakers used on the RailCorp 1500V dc system.

It provides all the necessary information to ensure that the dc circuit breakers are electrically suitable for the RailCorp 1500V network. (eg fault levels, operation, etc.)

It requires that the circuit breakers be physically interchangeable with the existing truck-mounted circuit breakers, mounted within brick cubicles.

2 References

The following documents contain provisions that, through reference in this text, provide further information and constitute provisions of this specification. At the time of publication, the editions indicated below were valid.

2.1 Australian and International Standards

AS/NZS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules)
IEC 60051-2:1984 Direct acting indicating analogue electrical measuring instruments and their accessories Part 2: Special requirements for ammeters and voltmeters
EN 50123 – 1 Railway Applications – Fixed installations, DC switchgear Part 1: General
EN 50123 – 2 Railway Applications – Fixed installations, DC switchgear Part 1: DC circuit breakers

2.2 Drawings

The following drawings form part of this specification:

EL0006165 1500V DCCB Base Frame Assembly
EL0006166 1500V DCCB Truck Outline
EL0006167 1500V DCCB Truck Front Panel Layout
EL0227687 1500V DCCB Busbars and Insulating Plate Details
EL0006169 1500V DCCB Racking Handle Assembly
EL0006170 1500V DCCB Brick Cubicle Layout
EL0006281 1500V DCCB External Control Wiring Connections

2.3 RailCorp Standards

Several significant sets of requirements applicable to 1500V DC High Speed Feeder Circuit Breakers are common to other classes of equipment and are set out in the following RailCorp standards. The equipment shall comply with the relevant requirements set out therein.

EP 00 00 00 13 SP Design Ranges for Ambient Conditions for Electric Power Equipment.
EP 00 00 00 12 SP Electric Power Equipment – Integrated Support Requirements.
3 Definitions & Abbreviations

BAR type DCCB control Bus Auto Reclose type of control. This is explained in detail in Section 6.2.2

FAR type DCCB control Feeder Auto Reclose type of control. This is explained in detail in Section 6.2.3.

Close An operator initiated action which causes the circuit breaker to close. May be either by SCADA, locally via the truck controls or by using the manual operating handle.

Electrically Closed The complete closing action of the circuit breaker is caused by electrical means, typically by a solenoid or closing coil.

Falling Voltage Trip Characteristic The current required to trip the circuit breaker is proportionally reduced as the actual voltage on the 1500V system decreases. This is sometimes referred to as impedance protection. See Section 5.7.

HIGH setting The increased trip setting due to the Remote Setting alteration See Section 5.12.

LOW setting The normal overcurrent trip setting

Main 1500V Circuit The main current carrying part of the circuit breaker which is alive at 1500V to frame. It excludes the control circuitry which can be disconnected from the rest of the circuit by fuses or links, but includes the arc chute, blowout coils, etc.

Reclose A close action initiated by the auto reclose controls on the circuit breaker.

Floating The system condition when a common return path used as the zero voltage reference level for the equipment or system is not necessarily connected to earth.

Trip Free Action The circuit breaker shall not be able to be held closed, either by hand or electrically, if it is closed onto a current that otherwise would cause the breaker to open.

Nominal voltage (Un) Voltage by which an installation or part of an installation is designated

Highest system voltage (Umax) Highest value given for the voltage in the continuous operating condition

Lowest system voltage (Umin) Lowest value given for the voltage in the continuous operating condition

Rated insulation voltage (UNm) Maximum value of the dc voltage for which the equipment is designed in respect to its insulation

Rated voltage (UNE) Voltage value given by the manufacturer, which combined with rated service current, determines the utilisation of the equipment and to which the corresponding tests and utilisation categories, if any, relate

Maximum arc voltage (Üarc) Maximum voltage appearing across the switching device during arcing
Conventional free-air thermal current (Ith) Current which may be used for the temperature-rise test of an equipment in free-air. This value is equal to or greater than the maximum value of the rated service current \( I_{ne} \) of the equipment

**Rated service current (I\( Ne \))** Value of current stated by manufacturer, taking into account the rated voltage \( U_{Ne} \), the continuous duty and the utilisation category and the protective enclosure type, if any

**Conductive part** Part capable of conducting current, although it may not necessarily be used for carrying service current

**Clearance** Distance between any conductive parts along a string stretched along the shortest distance between these conductive parts

**Clearance to earth** Distance between any conductive part and any part earthed or intended to be earthed

**High speed current limiting circuit breaker (H)** Circuit breaker with a break time sufficiently short to prevent the short-circuit current reaching the peak value it would have attained without interruption

For this condition to apply, the H circuit breaker has an opening time not greater than 5ms and a total break time not greater than 20ms, when the current to be interrupted has a prospective sustained value of at least 7 times the circuit breaker setting and \( \text{di/dt} > 6 \text{ kA/ms} \)

**Line circuit breaker (L) or feeder dcdb** Circuit breaker used to connect or disconnect a power line circuit to a dc source of supply. The power line circuit is that circuit which transmits the electrical energy to the electrical machines and traction equipment on the vehicles. These circuit breakers are fitted with electrical protection, control and operating devices. Line (feeder) circuit breakers are used to disconnect the track line from the energised busbar and are trip-free

**Critical current (Ic)** Value of breaking current, less than rated short circuit breaking current, at which the arcing time is a maximum and is significantly longer than at the rated short circuit breaking current

## 4 Functional Characteristics

### 4.1 General

The circuit breakers covered by this Specification will be used for the control and protection of 1500V track feeders in traction substations and sectioning huts on the RailCorp railway system.

The nominal voltage \( (U_n) \) of the traction supply is 1500V dc. The overhead conductors of the system are positive with respect to the rails, which are unearthed but normally close to earth potential.

The circuit breaker is required to detect faults on the 1500V system and to clear such faults as quickly as possible, to minimise damage to equipment, and with no damage to the circuit breaker – it is a line (L) high speed current limiting (H) circuit breaker, see Section 3.

The circuit breakers shall be physically interchangeable with truck-mounted circuit breakers installed in substations and sectioning huts in recent years.
The circuit breaker will be connected between the 1500V positive busbar and the feeder. The circuit breaker shall open automatically only when the direction of the fault current through the circuit breaker is away from the busbar. It shall not open automatically when current of any magnitude flows towards the busbar.

The circuit breaker shall detect faults by current magnitude, rate of rise of current and falling voltage – a magnetically held, high speed, current limiting circuit breaker.

All equipment on the circuit breaker is to be naturally cooled.

Two different types of automatic reclosing control schemes are required - BAR and FAR types. See Sections 6.2.2 and 6.2.3.

SCADA equipment will be installed in the substation to provide remote open and close signals for the control of the circuit breakers and remote indication of whether the circuit breakers are open or closed. Other remote indication and control as specified in this document will interface with SCADA.

### 4.2 Interchangeability

The circuit breakers shall be physically interchangeable with truck-mounted circuit breakers installed in substations and sectioning huts in recent years.

- The circuit breakers and trucks shall be equivalent in dimension and type to those shown on Drawings EL0006166 “1500V DCCB Truck Outline”, EL0006167 “1500V DCCB Truck Front Panel Outline” and EL0006170 “1500V DCCB Brick Cubicle Layout”. The dimensions shown on these drawings are critical and must be strictly adhered to.
- The connections to the external control wiring are to be made using “Cannon” type Multipin Plug and socket - ATC 02 A28 - 11P - F80 and ATC 06 A28 - 11S - F80 respectively, or plug and socket assemblies which are exactly compatible to the “Cannon” type Plug and Socket. The circuit breakers are to be wired in accordance with Drawing EL0006281 “1500V D.C.C.B. External Control Wiring Connections” and are to be complete with the neoprene rubber tubing and 1000 mm lengths of wire as shown on the drawing.

Circuit breaker base frames are the fixed portion onto which the circuit breaker is racked-in. The base frames shall comply with drawing EL0006165 “1500V DCCB Base Frame Assembly”.

Bus bar jointing pieces and insulating pieces are used to connect the 1500V bus portion of each base frame to its adjacent bus. The bus bar jointing and insulating pieces shall comply with drawing EL0227687 “1500V DCCB Busbars and Insulating Plate Details”

The circuit breaker shall be suitable to operate with arc expulsion spaces no greater than 3870mm above floor level.

### 5 Performance Characteristics

#### 5.1 General

The dc circuit breaker(s) (dccb) shall be high speed current limiting (H) indoor, truck mounted, single pole, electrically closed, electrically opened, trip-free, and suitable for use in a nominal 1500V dc circuit and specifically designed for traction duty. The dc circuit breaker exclusively operates by means of contacts which open and close in air at atmospheric pressure.
Each circuit breaker shall be supplied complete, with all of the auxiliary equipment necessary for control, protection and operation, mounted on the truck.

The dccb’s shall be installed in brick cubicles, in a manner that prevents damage to other dccb’s or substation equipment, in the event of a dccb flashover.

5.2 Voltage Rating

The circuit breaker shall operate satisfactorily with voltages in the range of 1000 to 2050V dc. Continuous operation at 2000V is not anticipated. The permissible temperature rise shall not be exceeded when the equipment is operated continuously at 1750V.

Voltage ratings are set out in document EP 90 20 00 02 SP – 1500V System Voltage Ratings.

5.3 Current & Short Circuit rating

The continuous and time varying load current rating and required short circuit performance are as set out in document EP 90 20 00 01 SP - “1500V DC Equipment Current Ratings”.

All requirements relating to feeder dccb’s of the Section ‘DC feeder equipment’ in EP 90 20 00 01 SP are applicable.

5.4 Reliability

Each circuit breaker is the only protection element for the associated section since there is no ‘back-up’ protection. It is therefore of utmost importance that the circuit breaker can:

- Reliably detect a fault.
- Reliably clear the fault.

The circuit breaker must:-

- Fail to an open state when any of its control or protection circuits fail.
- Fail to an open state when any control voltage is lost.
- Provide independent fault detection circuits.

5.5 Multiple Fault Operation

The circuit breaker shall be capable of being operated on the following fault cycle without damage and without requiring any maintenance, when interrupting a circuit with a prospective fault current of 8kA and initial rate of rise of 250kA/s:-

After the initial opening and one automatic reclosure,

- Five reclosures at 30 second intervals, followed by
- Five reclosures at 2 minute intervals, followed by
- Five reclosures at 30 second intervals, followed by
- Five reclosures at 2 minute intervals followed by
- Five reclosures at 30 second intervals, followed by
- Five reclosures at 2 minute intervals, followed by
- Five reclosures at 30 second intervals, followed by
- Five reclosures at 2 minute intervals.
5.6 Variability of Trip Level

The actual current required to trip the circuit breaker shall not vary by more than ±5% from the setting, for slowly increasing current and constant 1500V control voltage, with any fault up to the specified maximum fault rating.

5.7 Falling Voltage Trip Characteristic

As the busbar voltage falls, the current in the main circuit required to trip the circuit breaker shall also fall. The characteristic shall be continuous.

The relationship between the busbar voltage and the current in the main circuit required to trip the circuit breaker shall be as follows:

<table>
<thead>
<tr>
<th>Current in Main Circuit required to Trip Circuit breaker</th>
<th>Busbar Voltage (3000A Setting) Volts</th>
<th>Busbar Voltage (6000A Setting) Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% of Setting</td>
<td>1500 - 1575</td>
<td>1500 - 1575</td>
</tr>
<tr>
<td>50% of Setting</td>
<td>960 - 1060</td>
<td>740 - 810</td>
</tr>
<tr>
<td>Nil</td>
<td>440 - 480</td>
<td>300 - 330</td>
</tr>
</tbody>
</table>

Values between these points may be linearly interpolated.

Curves shall be provided showing the falling voltage trip characteristic graphed as current required to trip vs. voltage, for trip settings of 3kA, 4kA, 5kA, and 6kA.

It is permissible that as the busbar voltage increases, the current in the main circuit required to trip the circuit breaker also increases on a characteristic extrapolated from the above.

5.8 Current Rate of Rise Characteristic

The circuit breakers shall open at the calibrated current value for a slowly rising current and shall open at less than the calibrated current value for a rapidly rising current as detailed below:

<table>
<thead>
<tr>
<th>Initial rate of rise of current (A/s) - (±10%)</th>
<th>Current required to trip for 3000 A setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;75,000</td>
<td>3000</td>
</tr>
<tr>
<td>200,000</td>
<td>2600</td>
</tr>
<tr>
<td>400,000</td>
<td>2300</td>
</tr>
<tr>
<td>600,000</td>
<td>2200</td>
</tr>
<tr>
<td>2,000,000</td>
<td>2000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial rate of rise of current (A/s) - (±10%)</th>
<th>Current required to trip for 4500 A setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100,000</td>
<td>4500</td>
</tr>
<tr>
<td>200,000</td>
<td>4200</td>
</tr>
<tr>
<td>500,000</td>
<td>3600</td>
</tr>
<tr>
<td>1,500,000</td>
<td>3100</td>
</tr>
<tr>
<td>3,000,000</td>
<td>3000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial rate of rise of current (A/s) - (±10%)</th>
<th>Current required to trip for 6000 A setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;150,000</td>
<td>6000</td>
</tr>
</tbody>
</table>
The above figures also include the effect of the falling voltage trip characteristic when the 1500V control voltage is reduced by the application of the fault.

Values for other settings may be linearly interpolated.

5.9 Automatic Reclose Undervoltage Characteristic
The circuit breaker shall not reclose if the 1500V dc supply falls below a predetermined voltage in the range from 1000 to 1250V. This voltage shall be independent of the falling voltage trip characteristic of the circuit breaker.

5.10 Arc Voltage
When clearing any fault up to the specified maximum fault rating, the arc voltage shall not exceed 3500V or the rated impulse withstand voltage of the equipment.

5.11 Overcurrent Setting
The circuit breakers shall have an overcurrent setting range of 3kA to 6kA. The calibration shall be adjustable in a minimum of 500A steps and all calibration points shall be clearly marked.

5.12 Remote Setting Alteration
Means shall be provided to remotely increase the current trip setting of the circuit breaker by the application of a 125V dc positive signal. The setting shall remain high while this signal is applied and revert to the low setting when it is removed.

The magnitude of the setting increase shall be selectable on the circuit breaker, and shall be up to a 2000A increase in a minimum of 500A steps. The circuitry used to increase the setting shall be such that any failure in the circuit shall cause the setting to revert to the lower value.

(Note: The existing magnetically held circuit breakers use the Test Coil for this purpose.)

6 Technical Characteristics

6.1 Mounting of Controls and Auxiliary Equipment
Each circuit breaker (and truck if used) shall be self-contained with all of the auxiliary and control equipment required for the circuit breaker, including all of the control equipment to give the automatic reclosing as detailed below. The equipment shall be arranged such that cables are not flexed when doors are opened or the circuit breaker is racked-in and also to prevent the circuit breaker being racked-in unless the arc chute is in its correct position. An interlock shall be provided to prevent the circuit breaker from being withdrawn or racked-in while the circuit breaker is closed.

All conductors carrying 1500V dc must be physically segregated from voltages at lower potential (including ‘Earth’) by a distance which prevents any flash-over from high to low...
voltage conductors. All equipment connected to the 1500V dc circuit (such as coils, resistors etc.) must also be adequately segregated and comprise minimum protection against flash-over.

The minimum clearance in air between adjacent uninsulated 1500V dc conductors and between uninsulated 1500V dc conductors and earthed metalwork shall not be less than 25mm. The minimum creepage distance shall not be less than 37mm, of which at least 25mm shall be vertical.

Equipment connected to the 1500V dc circuit within switchboards shall be segregated from all other control and auxiliary equipment operating at lower voltages by suitable barriers or a physical separation of at least 50mm – as to AS/NZS 3000. All 1500V wiring shall be harnessed separately from other control and auxiliary wiring, and shall be designed for a test voltage of at least 5kV rms to earth for 1 minute.

6.2 Control of Circuit breakers

6.2.1 General

The circuit breakers shall be arranged for operation by local control or remotely by SCADA control. The SCADA equipment provides an open or close command signal of +125V dc at a maximum 0.5A for a duration of up to 1.0 second.

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 operation shall be trip-free.

The circuit breaker shall open without delay when the open command signal is applied.

The circuit breakers supplied shall have a provision for the manual selection of BAR or FAR type controls. The circuit breakers’ control logic shall be arranged such that conversion from Busbar-auto-reclose (BAR) to Feeder-auto-reclose (FAR) or vice versa shall not require alterations to any wiring, rather manually selected by field staff by means of a human-operated mechanical movement. The preferred means of operation is a ‘link’ type mechanism. The automatic reclose provisions detailed in the following shall apply for both local and SCADA control. In the following description, the word ‘alive’ shall be taken as meaning a voltage exceeding the setting described in Section 5.9.

6.2.2 BAR Type Circuit Breaker Controls

When a BAR type circuit breaker opens due to over-current in the main circuit, it shall reclose automatically after 30 seconds provided the bus bar is alive. If the circuit breaker then reopens within 5 seconds it shall remain open until another close signal is applied. If the circuit breaker does not reopen during those 5 seconds the automatic reclosing equipment shall reset.

It shall be possible to close the circuit breaker if the feeder is alive or the bus is alive.

6.2.3 FAR type Circuit Breaker Controls

The automatic reclosing of a FAR type circuit breaker shall be determined by the voltage on the 1500V feeder it controls. When a circuit breaker opens due to over-current in the main circuit it shall reclose automatically after 5 seconds if the feeder is alive. If the feeder is not alive at the end of the 5 second period the circuit breaker shall reclose automatically as soon as the feeder becomes alive.

It shall be possible to close the circuit breaker if the feeder is alive or the bus is alive.
6.3 Control Supplies

6.3.1 General

The substation battery system is 125V dc, as outlined in EP 06 00 00 01 “System Substation Battery”.

Control supply for the operation of the circuit breaker shall only be obtained from the 125V dc battery and/or the 1500V system. All wiring connected through the circuit breaker control plug/socket shall be rated for 125V.

6.3.2 125V Controls

The 125V control equipment shall be continuously rated for operation on a nominal 125V dc supply and shall be capable of satisfactory operation with voltage variations of +10/-20% of the nominal 125V. The actual voltage output of the 125V battery system at any given time will fall within these voltage variations.

All 125V control wiring shall be designed to withstand a test voltage of 1.5kV rms to frame for 1 minute and 5kV rms to main 1500V circuit for 1 minute.

6.3.3 1500V Controls

The 1500V control equipment shall operate satisfactorily within the voltage rating specified in Section 5.2.

The average current drawn from the 1500V system for the control circuits shall not exceed 300 mA.

The 1500V supply for controls shall be derived from both the busbar side of the circuit breaker and the feeder side of the circuit breaker. The equipment shall be configured such that the 1500V control supply is available if either the busbar or the feeder is alive.

All 1500V control circuits shall be protected by HRC fuses. The number of such fuses should be kept to a minimum and the fuses supplied shall be of proved breaking capacity. Expulsion type fuses shall not be used.

6.4 Auxiliary Indication Contacts.

In addition to the any contacts required for the control and operation of the circuit breaker two normally open and two normally closed, voltage-free auxiliary contacts shall be provided to indicate if the circuit breaker is open or closed. All auxiliary contacts shall have a minimum make and break rating of 1 Amp at 125V dc and 5A at 240V ac and shall have dust proof covers. They shall withstand a voltage of 5kV rms to the main 1500V circuit for 1 minute. The contacts shall be operated by a linkage directly from the main contacts, not from the driving/operating mechanism.

6.5 Increased Setting Indication Contacts.

One set of normally open and normally closed, volt-free auxiliary contacts shall be provided to indicate if the “increased” or “standard” setting is in use. (see Section 5.12.) These auxiliary contacts shall have a minimum make and break rating of one amp at 125V dc and 5A at 240V ac and shall have dust proof covers. They shall withstand a voltage of 5kV rms to the main 1500V circuit for 1 minute.
All controls and wiring required for this feature must withstand 1.5kV rms to earth for 1 minute.

6.6 Manual Operation
It shall be possible to close the circuit breaker by hand with a trip free action (see Section 3). A handle for closing during maintenance is to be provided.

6.7 Mechanical Open/Close Indicator
The circuit breaker shall be fitted with a mechanically operated indicator, indelibly marked, to show whether the circuit breaker is open or closed. It is not necessary that this indicator is visible from the front of the circuit breaker truck in its normal racked-in position. 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.

6.8 Local Control and Indication
Visual indication of the state of the circuit breaker shall be provided by LEDs mounted on the front of the truck. Red colour shall be used to indicate closed and green to indicate open.

Means shall be provided on the front panel, to open and close the circuit breaker locally. If colours are used, then the colour green shall indicate the action device to open the circuit breaker. The colour red shall indicate the action device to close the circuit breaker.

6.9 Test Button
A Test button, yellow in colour, shall be provided on the front of the truck. Operation of this button shall simulate the tripping of the circuit breaker on fault. Operation of the test button shall not inhibit the normal automatic re-close function of the circuit breaker.

6.10 Arc Chute
An Arc Chute Barrier shall be provided and mounted by the manufacturer. The barrier shall be able to prevent an arc from coming into contact with any metalwork in the area of arc expulsion.

6.11 Operation Counter
A non-resettable, memory-retentive counter shall be provided to record the number of openings on the circuit breaker.

6.12 Current Measurement and Indication

6.12.1 Ammeter
Each circuit breaker shall be fitted with a meter indicating dc current.

This meter shall be mounted on the front of the truck and shall be insulated from the 1500V circuit. The insulation to the 1500V circuit shall withstand 5kV rms for 1 minute.

The ammeter shall be capable of displaying -2 kA to +8 kA with an accuracy of 2.5%.
If an analogue meter is provided it shall have a scale length of at least 150 mm and shall comply with IEC 60051-2, 1984 “Direct acting indicating analogue electrical measuring instruments and their accessories Part 2: Special requirements for ammeters and voltmeters”.

If the ammeter is not connected to a transducer, rather directly to the shunt resistor, it shall be constructed with a thermoplastic case, glass window with no zero adjustment option.

If a digital meter is provided it shall have a resolution of at least 100A.

6.12.2 Isolated Current Output

An output signal, isolated from the 1500V circuit, shall be provided to allow current measurement ‘off the truck’. Connections shall be via the plug/socket. The output shall provide a ±10V signal for ±10, 000A input.

A frequency response of at least 1000 Hz is required.

This signal may also be used to operate the ammeter on the circuit breaker.

6.13 Materials

Asbestos is not to be used in any part of the equipment.

Special attention is required to use of materials with the ability to resist moisture and fire; materials used should be of the self-extinguishing type, such that the risk of propagation of fire from one cubicle to another is minimised.

Materials and products of combustion shall be practically halogen free and shall contribute with limited quantity of thermal energy to a fire.

6.14 Environment

The circuit breakers will be installed inside traction substation and sectioning hut buildings. The equipment shall comply with the requirements of EP 00 00 00 13 SP “Electric Power Equipment - Design Ranges of Ambient Conditions”.

6.15 Noise Emissions

The peak sound pressure level during the interruption of a fault shall be stated in the schedule at Appendix A. The sound pressure level shall be stated for the circuit breaker mounted on the truck, with the truck in a standard cubicle and at a point 1m in front of the truck. The sound pressure level quoted shall be the maximum level over the full range of fault current interruption.

7 Routine Maintenance Period

Routine maintenance shall not be required more frequently than:

- Once every six months, or
- After 50 fault openings.
8 Integrated System Support Requirements

8.1 Integrated Support Objectives

The tenderer 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 DC Feeder Circuit Breaker.

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 a new DC Feeder Circuit Breaker. Manuals, training, documentation and other support deliverable's shall be in accordance with EP 00 00 0012 SP "Electrical Power Equipment - Integrated Support Requirements."

9 Routine Tests

9.1 General

The supplier shall carry out the Routine Tests detailed in this section, on every circuit breaker supplied.

9.2 Dielectric Tests

9.2.1 Acceptance Criteria for Dielectric Tests

The following dielectric tests shall be considered to have been passed if there is no flashover, sparking-over, puncture, surface tracking, obvious deterioration of the insulation or any other indication of failure of the below mentioned conductors, circuits and all equipment connected to these circuits.

9.2.2 Main 1500V dc Circuit to Frame

For this test any control and auxiliary circuits that are not normally connected to the main 1500V circuit shall be connected to the frame. A dielectric test voltage of 5kV rms shall be applied between the main circuit and the frame of the circuit breaker with the main contacts in the open position for a minimum of 1 minute. This test shall be repeated with the main contacts in the closed position.

9.2.3 Across the Main Contacts

A dielectric test voltage of 5kV rms shall be applied directly across the main contacts when in the open position, for a minimum of 1 minute.
9.2.4 125V Circuits to Main 1500V dc circuit
For this test the main 1500V circuit shall not be connected to the frame. The dielectric test voltage of 5kV rms shall be applied for a minimum of 1 minute between all of the 125V control and auxiliary circuits with the ammeter and isolated current output circuits connected together - and the main 1500V circuit. (The frame is considered to be 'floating'.)

9.2.5 125 V Circuits to Frame
For this test, the main 1500V circuit shall be connected to the frame. The dielectric test voltage of 1.5kV rms shall be applied for a minimum of 1 minute between all the 125V control and auxiliary circuits with the ammeter and isolated current output circuits connected together and the frame.

9.2.6 1500V Control Circuits to Frame
For this test the 1500V control circuits shall be disconnected from the main 1500V circuit and the main 1500V circuit shall be connected to frame. The dielectric test voltage of 5kV rms shall be applied for a minimum of 1 minute between all of the 1500V control circuits connected together, and the frame of the circuit breaker.

9.3 Calibration of the Trip Current Value
Adjust the circuit breaker trip setting to 3000A.

With all other parameters held constant and the circuit breaker closed, the current shall be slowly increased from zero until the circuit breaker trips and the trip value recorded. The test shall be repeated 20 times and the actual trip current shall not deviate from the set value by more than ±5%.

Repeat the test with the circuit breaker set at 4kA, 5kA and 6kA.

This test may be carried out with the test current in the main circuit applied at a low voltage.

This test is to be carried out before all other tests and at the completion of all other tests.

9.4 Operation at High and Low Control Voltages
Operating tests shall be carried out to demonstrate that the circuit breaker meets the specified operating conditions at the upper and lower limits of supply voltage specified for the control device during closing and opening.

The following tests shall be applied:

   a) At the maximum control supply voltage specified in Section 6.3.2 and with 1500V on the 1500V circuit:-
      Five (5) closing operations and five (5) opening operations.

   b) At the minimum control supply voltage specified in Section 6.3.2 and with 1500V on the 1500V circuit:-
      Five (5) closing operations and five (5) opening operations.

   c) With 1000 volts on the main 1500V circuit and 125V control supply:-
      Five (5) closing operations and five (5) opening operations.
d) With 2000 volts on the main 1500V circuit and 125V control supply:-

Five (5) closing operations and five (5) opening operations.

The tests shall be carried out without current in the main circuit, except when necessary for the operation of releases.

During the tests, no adjustment shall be made and the operation shall be satisfactory.

Following these tests, the circuit breaker shall be examined to ascertain whether any of its components have been damaged and that all parts are in satisfactory operating condition.

10 Type Tests

10.1 General

No dc circuit breaker shall be used on the RailCorp system unless a circuit breaker of that build has successfully passed an approved type test. The standard RailCorp type tests are set-out in Appendix D Other testing regimes are subject to approval by RailCorp on a case-by-case basis.

11 Data Set associated with the Equipment

The following data shall be maintained for the dc circuit breakers. This data will remain the property of RailCorp.

11.1 Test Results

The results of all tests, including acceptance tests and periodic and corrective maintenance tests, shall be recorded and maintained.

Routine Tests certificates showing the results of each test made on each circuit breaker shall be supplied in duplicate, in English, no later than at the time of delivery of the circuit breakers.

Type Test certificates showing the results of each test shall be supplied in duplicate and electronically, in English, and maintained for the life of the equipment.

11.2 Life Cycle Costing

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

11.3 Information to be Provided

The information listed in the attached Technical Schedule at Appendix A shall be maintained for each circuit breaker.
Appendix A  Technical Schedule

Circuit Breaker Details

DCCB Manufacturer .....................................................

DCCB Manufacturer’s type number ..................................

Current rating (continuous) ......................................... A

Voltage ratings

- Nominal voltage ($U_n$) ................................................. $V_{dc}$
- Highest system voltage ($U_{max}$) ................................. $V_{dc}$
- Lowest system voltage ($U_{min}$) ................................. $V_{dc}$
- Rated insulation voltage ($U_{Nm}$) ............................ $V_{dc}$
- Rated voltage ($U_{Ne}$) .............................................. $V_{dc}$

Maximum permissible prospective current .................. kA/sec

Maximum permissible di/dt at t=0 ............................... kA/sec

Break time as a function of rate of rise of current (di/dt). May need to provide graph

Critical current ($I_c$) .................................................. A

Mass of circuit breaker including arc chute and truck complete with control gear ........................................... kg

Mass of complete circuit breaker ................................... kg

Mass of arc chute ........................................................ kg

Control circuit technology  N  Y  Type/details

- Logic and timing
  o Relays .................................................................
  o Electronic cards ................................................. N/A N/A N/A
  o PLC or other programmable device .........................
- Closing coil switch
  o Contactor ...........................................................
  o Electronic device ................................................
- Under voltage detection
  o Fixed threshold ..................................................
  o Isolation technology ...........................................
  o Isolation level ...................................................
  o Comment on previous use of above technology .......

Closing time ............................................................ msec
<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting range</td>
<td>to kA</td>
</tr>
<tr>
<td>Minimum setting steps</td>
<td>A</td>
</tr>
<tr>
<td>Heat Loss - No Load (0%)</td>
<td>kW</td>
</tr>
<tr>
<td>Full Load (100%)</td>
<td>kW</td>
</tr>
<tr>
<td>Number of main contacts in series</td>
<td></td>
</tr>
<tr>
<td>Number of main contacts in parallel</td>
<td></td>
</tr>
<tr>
<td>Total area of main contacts</td>
<td>mm²</td>
</tr>
<tr>
<td>Are arcing contacts used?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Conventional free-air thermal current (Iₚₚ)</td>
<td>A</td>
</tr>
<tr>
<td>Rated service current (Iₑₑₑₑ)</td>
<td>A</td>
</tr>
<tr>
<td>Distance between main contacts when circuit breaker is open</td>
<td>mm</td>
</tr>
<tr>
<td>Distance between arcing contacts when circuit breaker is open</td>
<td>mm</td>
</tr>
<tr>
<td>Main contact material</td>
<td></td>
</tr>
<tr>
<td>Maximum arc voltage (Uₘₘₘₘ) With circuit conditions</td>
<td></td>
</tr>
<tr>
<td>Are blow-out coils used?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Is an auxiliary blow-out coil used in arc chute?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Does the circuit breaker contain components manufactured wholly or partly with asbestos?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Arc chute material</td>
<td></td>
</tr>
<tr>
<td>Method of determining arc chute wear</td>
<td></td>
</tr>
<tr>
<td>Maximum wear measurement allowed before arc chute is replaced.</td>
<td>mm</td>
</tr>
<tr>
<td>Minimum clearance in air to earth of uninsulated 1500V conductors</td>
<td>mm</td>
</tr>
<tr>
<td>Minimum clearance in air between uninsulated conductors which may have a potential difference of 1500V</td>
<td>mm</td>
</tr>
<tr>
<td>Minimum creepage distance to earth of uninsulated 1500V conductors</td>
<td>mm</td>
</tr>
<tr>
<td>Material over which the above-mentioned creepage distance applies</td>
<td></td>
</tr>
<tr>
<td>Maximum peak sound pressure level</td>
<td>dB</td>
</tr>
<tr>
<td>Minimum arc expulsion space height</td>
<td>mm</td>
</tr>
<tr>
<td>Max arc expulsion space above floor level</td>
<td></td>
</tr>
<tr>
<td>Max clearance around arc chute/breaker?</td>
<td></td>
</tr>
<tr>
<td>Number of 1500V fuses to protect 1500V control circuits</td>
<td></td>
</tr>
<tr>
<td>Allowable erosion of the arc chute before replacement is required...</td>
<td>mm</td>
</tr>
<tr>
<td>Type of insulating material in contact with conductors of main circuit</td>
<td></td>
</tr>
</tbody>
</table>
Tests

One minute voltage withstand test at 50 Hz:
- Between contacts (breaker open) .................................................. kV rms
- Main 1500V circuit to frame .................................................. kV rms
- Main circuit to 125V circuit .................................................. kV rms
- 125V circuit to frame .................................................. kV rms
- 1500V Control circuit to frame .................................................. kV rms

Impulse voltage withstand test with waveform:
- Between contacts (breaker open) .................................................. kV rms
- Main circuit to frame (earth) .................................................. kV rms
- Main circuit to operating circuit .................................................. kV rms

Temperature rise of hottest part:
- After continuous operation at rated current .................................................. °C
- After 2 hour's operation with duty cycle specified in Sec 5.3 .................................................. °C

Type tests:
- Proposed type tests – RailCorp in accordance with Appendix D or Alternative?
- If alternative – what are the differences?

Coils

Coil Characteristics (if fitted):
- Holding coil Manufacturer and type number ........................................
- Holding coil current rating .................................................. A
- Holding coil power rating .................................................. watts
- Closing coil power rating .................................................. watts
- Holding coil resistance at 20°C .................................................. Ohms
- Holding coil series resistance at 20°C .................................................. Ohms
- Closing coil resistance at 20°C .................................................. Ohms

Test Coil Characteristics (if fitted):
- Test coil resistance at 20°C .................................................. Ohms
- Continuous current rating of Test Coil .................................................. A

Setting Calibration:
Distance between adjacent 500A calibration marks on calibration scale .................................................. mm
Describe the Method used to adjust the LOW setting:
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Describe the Method used to adjust the HIGH setting:
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Describe the method of Remotely increasing the setting:
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Describe the method of ensuring the setting ‘fails’ to the LOW setting:
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
Life Cycle and Support

With a fault current of 8kA and 6mH of inductance, what is the service life of the following items:

<table>
<thead>
<tr>
<th></th>
<th>Number of fault openings before inspection required</th>
<th>Number of fault openings before maintenance required</th>
<th>Cost of such maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc chute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arcing contacts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main contacts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What is the evidence used to justify the service life claimed above?

..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................

Period for which the supplier will support the equipment with parts and support personnel:.................years

Describe the method of changing the circuit breaker from Busbar-auto-reclose to Feeder-auto-reclose or vice versa:

..........................................................................................................................................
..........................................................................................................................................

Maintenance

Details of maintenance requirements & frequency:

<table>
<thead>
<tr>
<th>Type of Maintenance</th>
<th>period (months)</th>
<th>approx. hours involved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B  Request for Tender Checklist

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

The RFT is to include a statement that all standards and specifications are subject to revision, and parties to agreements based on this specification are required to apply requirements of the most recent editions.

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:

Specific deliverable’s including:

- Spare contacts.
- Spare fuses.

Information to be sought from the Tenderer

- Integrated Support information as per RailCorp Standard
- Tenders to complete and submit Technical Schedule in Schedule A
- Provision of general arrangement and sectional elevations of circuit breaker showing overall dimensions, required space for removing arc chute, required space to insulated and/or earth parts.
- Schematic diagram
- Characteristics of the circuit breaker (i2t or break time) of circuit breaker
- Oscillographic records showing circuit breaker performance under the interrupting conditions.
Appendix C  Requirements for Technical Aspects of Tender Evaluation

Evaluation of tenders
The Chief Engineer Electrical requires that persons evaluating the technical aspects of this tender have sufficient technical competence for the task.

Tender evaluation committees shall forward details of persons evaluating the technical aspects of the tender to the Chief Engineer Electrical for concurrence. This will normally be in the form of an email and is to include sufficient detail of the tender and the person to enable the Chief Engineer Electrical to satisfy themself of the merits of the evaluating person. A minimum of 4 weeks notice is required prior to the evaluation of the Tenders.

The Chief Engineer Electrical will advise only if the person is considered unsuitable for the technical evaluation.

Acceptance of product
A number of the specifications require acceptance of product at both the factory and at site. The purchaser is to advise the Chief Engineer Electrical the details of the person carrying out the acceptance testing for the concurrence of the Chief Engineer Electrical. A minimum of 4 weeks notice is required prior to the evaluation of the acceptance testing.

The Chief Engineer Electrical will advise only if the person is considered unsuitable for the acceptance testing.

The Chief Engineer Electrical reserves the right to nominate a representative to review and/or attend such acceptance.

Record Keeping
Where product is purchased against this specification, the Chief Engineer Electrical requires that relevant detail be provided so that it can be logged against this specification.

For RailCorp purchases, the tender evaluation committee shall advise the Chief Engineer Electrical the RailCorp registered file details containing the tender evaluation for future referencing. This is normally a TRIM reference.

Where this specification is utilised by parties external to RailCorp (Alliance parties, etc) then copies of all relevant technical information and evaluation shall be forwarded to the Chief Engineer Electrical for filing against the specification. In addition copies of selected commercial information pertaining to the ongoing support of the product as follows is also required.

- Warranty details
- Spare parts and associated availability
- Product support information.
Appendix D  RailCorp Standard Type Tests

All of the Type Tests shall be performed on the same circuit breaker (including the arc chute). No adjustments shall be made during the course of all these Type Tests.

At conclusion of all the Type Tests, there should be no more than 5% of the allowable arc chute material eroded.

All tests shall be carried out with 1500V dc control voltage.

Mechanical and Endurance Tests

Calibration of the trip current value

The tests described in Section 9.3 shall be carried out before the Mechanical & Endurance Tests of this section and at the completion of these Tests. In both cases the actual trip current shall not deviate from the set value by more than ±5%.

Mechanical Operation Test

The following shall be proved:-

Satisfactory tripping of the circuit breaker with the closing device energised.

Satisfactory behaviour of the circuit breaker when the closing operation is initiated with the tripping device actuated.

Mechanical endurance test

The circuit breaker shall undergo 1500 operating cycles consisting of a closing operation followed by an opening operation. This test shall be carried out at a minimum rate of 10 cycles per hour. The test may be carried out without current in the main circuit of the circuit breaker. No adjustment or maintenance is to be carried out on the circuit breaker for the duration of the test.

Electrical endurance test

The circuit breaker shall undergo 500 operating cycles consisting of a making operation followed by a breaking operation of its continuous rated current at its operational voltage. The circuit breaker trip setting shall be set at a value higher than the continuous rating. The minimum number of operating cycles shall be 10 cycles per hour with the circuit breaker to remain closed for a maximum of 2 seconds. No adjustment or maintenance is to be carried out on the circuit breaker for the duration of the test.

The circuit breaker must not fail to open or close during this test.

Ability to Withstand Short Circuit

Adjust the circuit breaker to trip at 5kA.

With a prospective current of 75kA @ 6000kA/sec initial rate of rise, the following sequence of events is to occur:-

- The fault is applied to the closed circuit breaker and it trips; then
- reclose 30 seconds later onto same fault and it trips again.
Ability to Withstand Multiple Faults

Adjust the circuit breaker to trip at 5 kA.

With a prospective fault current of 8kA @ 250kA/sec initial rate of rise, the fault is applied to the closed circuit breaker and it trips; then

- Six reclosures onto fault at 30 second intervals, followed by trip.
- Five reclosures onto fault at 2 minute intervals, followed by trip.
- Five reclosures onto fault at 30 second intervals, followed by trip.
- Five reclosures onto fault at 2 minute intervals, followed by trip.
- Then,
  - With a prospective fault current of 5.5kA @ 250kA/sec initial rate of rise,
  - a fault is applied to the closed circuit breaker and it trips; then
  - Six reclosures onto fault at 30 second intervals, followed by trip.
  - Five reclosures onto fault at 2 minute intervals, followed by trip.
  - Five reclosures onto fault at 30 second intervals, followed by trip.
  - Five reclosures onto fault at 2 minute intervals, followed by trip.

Then repeat all the above tests from Sections “Ability to Withstand Short Circuit” and “Ability to Withstand Multiple Faults”.

Temperature Rise Tests

Cyclic loading test

The circuit breaker shall be operated on the duty cycle specified below:-

- 5600A for 2.5 minutes followed by 1600A for 9.5 minutes with the 12 minute cycle being repeated for 2 hours.

The temperature rise of the various parts shall not exceed the values in the Technical Schedule at Appendix A.

This test may be carried out with the test current in the main circuit applied at a low voltage.

Continuous current test

The circuit breaker shall carry 3000A dc for a period of time sufficient for the temperature rise of all parts to become constant (rate of change less than 1 °C per hour). The temperature rise of the various parts shall not exceed the values in the Technical Schedule at Appendix A.

This test may be carried out with the test current in the main circuit applied at a low voltage.

Initial Loading Tests

Adjust the circuit breaker to trip at 4kA.

a) Close the circuit breaker onto a circuit with 15 mH inductance and the circuit resistance adjusted to give 3000A at 1500V dc through the main circuit of the circuit breaker.

b) After the current in the main circuit has stabilised at 3000A, short out part of the resistance to increase the current through the circuit breaker to between 5000A and 6000A.
The circuit breaker shall not open at step (a) and it shall be open without delay in step (b).

Then adjust the circuit breaker to trip at **6kA**.

c) Close the circuit breaker onto a circuit consisting of 15 mH inductance and the resistance adjusted to give 4500A to 5000 A.

d) After the current in the main circuit has stabilised, short out part of the circuit resistance such that the resultant current through the main circuit increases to between 7000A and 8000 A at 1500V dc.

The circuit breaker shall not open at step (c) and it shall be open without delay in step (d).