Specification

DC Traction Switchgear and Controlgear

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1 PURPOSE

The purpose of this specification is to specify the minimum requirements of DC Traction switchgear and associated controlgear, which are to be installed within DC traction substations on the Yarra Trams network.

The configuration, ratings and any other project specific equipment details shall be provided by Yarra Trams in the accompanying *Scope of Works* document.

2 SCOPE

The scope of this specification encompasses the design and construction requirements for all new DC Traction switchgear and controlgear. This specification does not apply retrospectively to existing DC Traction switchgear and controlgear on the Yarra Trams network. However, this specification is applicable if existing DC Traction switchgear and controlgear is being altered, modified or replaced.

This specification applies to any party who is involved in the design or construction of DC Traction switchgear and controlgear for Yarra Trams.

3 COMPLIANCE

Any party who is involved in the design or construction of DC Traction switchgear and controlgear for Yarra Trams shall fully comply with this specification. Deviation from this specification is only permitted when a deviation or waiver has been formally requested and approved as the per Yarra Trams Deviation from Standards procedure.

The Yarra Trams Engineering Change Management Procedure [CE-021-PR-0020] shall be followed in all circumstances where change is proposed to this specification.

The following definitions apply throughout the specification:

- 'Shall' statements are mandatory in the context of compliance with requirements stipulated in this specification.
- 'Should' statements are considerations in the context of compliance with requirements stipulated in this specification.
- 'Information' statements provide additional content for clarification purposes only and are not requirements in the context of compliance with this specification.
- 'So far as is reasonably practicable' statements must at a minimum result in the provision of a technical risk assessment including proposed list of design controls to demonstrate compliance to this specification.

4 REQUIREMENTS

4.1 Service conditions

4.1.1 Operating conditions

4.1.1.1 The DC Traction switchgear and controlgear shall be indoor and may also be underground.

4.1.1.2 The operating conditions are defined in the Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037].

4.1.2 Transport and storage climatic conditions

4.1.2.1 The transport and storage conditions are defined in the Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

4.1.2.2 The *Designer* shall detail the minimum storage requirements. This information shall be contained in the equipment manuals, which are outlined in Table 10.

4.1.3 Noise

4.1.3.1 The permissible noise levels inside and outside the substation are defined in the Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

4.1.4 Electromagnetic compatibility (EMC)

4.1.4.1 The electromagnetic compatibility requirements are defined in the Infrastructure -Network Power – Substation - Design and Construction [CE-021-ST-0023].

4.2 General requirements

4.2.1 General

4.2.1.1 The DC Traction switchgear and controlgear shall be metal-enclosed switchgear complying with the latest revisions of the following standards:

- EN 50123-1.
- EN 50123-6; and
- EN 50123-7-1.

4.2.1.2 The DC Traction Feeder Panels and controlgear comprises one or more of the following items of equipment:

- Transfer switches (see section 4.4);
- Short circuiting switches (see section 4.5);
- Transducers and measurement devices for DC Traction current measurements (see section 4.2.12);
- Interlocking; and
- Control and protection devices.

Information: short circuiting should be considered to be isolated in separate isolator cubicle

4.2.1.3 These items of equipment are arranged and installed in separate compartments (preferably with one panel per DC circuit breaker). Each panel generally consists of separate compartments as follows:

- DC circuit breaker compartment;
- Transfer switch compartment (where applicable);
- Short-circuiting switch compartment (where applicable);
- Busbar compartment (positive, transfer and negative busbars);
- Power cable terminal compartment; and
- Low voltage control, protection and line test device compartment.

Information: low voltage compartments are to be isolated from the high/medium voltage compartments.

4.2.1.4 The DC Traction switchgear and controlgear shall be able to be electrically controlled and/or indicated locally and remotely through the SCADA system, as specified using the Control Voltage.

4.2.1.5 The configuration of the DC Traction switchgear depends on the specific arrangement for the substation and shall be defined in the *Scope of Works*.

Information: Typical single line diagrams of a single rectifier substation and dual rectifier substation are provided in the Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

4.2.1.6 The DC Traction switchgear shall meet the following requirements:

Table 1: General requirements

Description	Requirement
Nominal voltage, U_n	600 V DC with being able to be operated at U_n of 750 V DC in the future
Rated voltage, U_{Ne} (for main circuits)	As defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037].
Power frequency withstand voltage level, U_a (for main circuits)	As defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037].
Rated impulse voltage, U_{Ni} (for main circuits)	As defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037].
Rated service current, I_{Ne} (for main circuits)	To be determined by the *Designer*
Rated short-time withstand current, I_{Ncw} (for main and earthing circuits)	The I_{Ncw} rating is the same value as the I_{Nss} rating for a time duration of 250 ms.

Description	Requirement
	(According to clause 6.18 of EN 50123-6)
Rated short circuit current, I_{Nss} (for main and earthing circuits)	70 kA
Peak of the short circuit current, $\hat{I}_{SS}$ (for main and earthing circuits)	Conventionally assumed to be 1.42 times the prospective sustained short-circuit current for a fault of negligible impedance at the input or output terminals of the switchgear. (According to clause 5.1.1.2 of EN 50123-1)
Rated duration of short circuit (for main and earthing circuits)	250 ms
Type of metal-enclosed switchgear	Metal-clad switchgear
Separate compartment for auxiliary and control equipment	Yes
Partitions and shutters	Non Metalic for DC Switchgear
Busbar material	Copper
Internal arc classification	AFLR
Rated auxiliary and control supply voltage	48 V DC

4.2.1.7 The *Designer* is fully responsible for providing suitable ratings for the DC Traction switchgear and shall therefore verify the values in Table 1.

4.2.2 Insulation coordination

4.2.2.1 The insulation levels are defined in the Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023] and EN 50123-6 as listed in the related Regulations and Standards in Section 6.

4.2.3 Earthing and bonding

4.2.3.1 The frames of the DC Traction switchgear cubicles shall be connected to rail earth through a frame leakage relay in accordance with the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037]. The insulating material, installed between the frames of the DC Traction switchgear cubicles and earth, shall provide an isolation resistance of at least 1 MΩ.

4.2.3.2 All other requirements are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037].

4.2.4 Enclosure

General

4.2.4.1 The minimum degree of protection provided by the enclosure (according to AS 60529) shall be IP41.

4.2.4.2 Interlocking requirements for the enclosure are covered in Section 4.2.6.

Circuit breaker truck

4.2.4.3 The circuit breaker truck shall be mounted on the floor of the substation. Separate trolley or tray systems for retrieval and movement of circuit breakers shall not be acceptable.

4.2.4.4 The circuit breaker truck shall have four positions:

- 'Service' position (Yarra Trams terminology = IN SERVICE);
- 'Test' position (Yarra Trams terminology = TEST);
- 'Disconnected' position (Yarra Trams terminology = ISOLATED); and
- 'Removed' position (Yarra Trams terminology = WITHDRAWN).

4.2.4.5 Access to measurement signals through the control panel shall not require withdrawal of the circuit breaker truck. However, these signals must be provided through safe isolation signal transducers

4.2.4.6 The truck shall be interlocked as specified in section 4.2.6.

4.2.4.7 The truck shall consider the human factor requirements listed in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2.4.8 The circuit breaker trucks shall be coloured according to their function; there shall be a unique colour for each type of DC circuit breaker (i.e. rectifier circuit breakers, feeder circuit breakers and bus-tie circuit breakers).

4.2.4.9 A sufficiently large handle suitable for two-handed operation shall be provided and shall be located on the front panel. Movement of this handle shall give ergonomic mechanical advantage for separation or connection of the power contacts with the busbars.

4.2.4.10 The solenoid, unlocking handles and mechanisms shall be of sufficient strength to prevent damage to the mechanism or truck should the handle be accidentally forced without unlocking.

4.2.4.11 An alternative system of circuit breaker withdrawal may be suggested.

Transfer switch truck

4.2.4.12 The transfer switch truck shall be designed for safe and ergonomic withdrawal and removal in accordance with Manual Handling procedures. Separate trolley or tray systems for retrieval and movement of transfer switches shall not be acceptable.

4.2.4.13 The truck shall be withdrawable whilst the main bus is alive and shall be independent of the operation or truck position of the main circuit breaker.

4.2.4.14 The operation, withdrawal and insertion of the truck shall be interlocked as specified in section 4.2.6 and the ergonomic requirements listed in Infrastructure – Network Power – Substation –

Design and Construction [CE-021-ST-0023] and Infrastructure – Network Power – Traction Power – Design and Construction [CE-021-ST-0037].

Dimensions

4.2.4.15 The DC Traction switchgear enclosure shall be designed to minimise the overall size (and subsequently the physical size of the substation) while meeting the requirements of specifications and standards.

Covers and doors

4.2.4.16 The covers and doors which are part of the enclosure shall be metallic. When they are closed, they shall provide the same degree of protection as specified for the enclosure. Covers or doors shall not be made of woven wire mesh, expanded metal or similar.

4.2.4.17 A rear access panel shall be provided for the inspection and maintenance of the cable terminations on the DC Traction busbar. This panel shall be a fixed cover, as per clause 6.7 of BS EN 50123-6 and shall not be possible to be opened, dismantled, or removed without the use of tools.

4.2.4.18 Feeder panels shall be able to be installed against the wall in order for cable terminations to be accessible from the front of the panel

Ventilating openings

4.2.4.19 Ventilated openings shall be arranged or shielded so that they provide the same degree of protection as specified for the enclosure. Such openings may make use of wire mesh or the like provided that it is of suitable mechanical strength.

Arc fault pressure relief flaps and gas exhaust ducts

4.2.4.20 The arc fault pressure relief flaps and gas exhaust ducts shall be designed in such a manner as to prevent injury should an incorrect operation or fault occur

4.2.4.21 The arc fault pressure relief flaps and gas exhaust ducts should be designed to prevent injury to any persons when in discharge mode

Inspection windows

4.2.4.22 Inspection windows shall be provided for short-circuiting switches. They shall comply with clause 6.8 of BS EN 50123-6.

4.2.4.23 Suitable inspection windows shall be provided for thermography of major power connections

Partitions and shutters

4.2.4.24 The shutter shall have an aperture for the main power plug contacts of minimum possible practical size that can accommodate all items such as the busbar and cable contact clusters of the DC circuit breaker, and that is suitably labelled with warning signs.

Test point

4.2.4.25 Access shall be provided in each feeder panel to the main busbar for the purpose of inserting a test probe to confirm energisation status of the main bus and to confirm test probe operation for testing of other apparatus. An additional test point access shall be provided for testing of the feeder cable flag. The test point shall be designed to prevent accidental contact with the test point conductors during the test process.

4.2.5 Protection

General

4.2.5.1 The protection system design shall provide the necessary functionality for minimising hazards to personnel, minimising damage to equipment and achieving appropriate discrimination to minimise equipment outages.

4.2.5.2 The DC Traction protection systems shall comply with EN 50123-7-1.

4.2.5.3 The DC Traction switchgear shall include at least the following protection:

- Instantaneous direct acting overcurrent release protection with adjustable setting range (direct acting);
- Undervoltage protection;
- Protection relay (indirect acting and high speed tripping);
- Manual/Emergency trip protection;
- Frame leakage protection;
- External tripping protection; and
- Surge protection.

Instantaneous direct acting overcurrent release protection with adjustable setting range (direct acting)

4.2.5.4 All DC Traction circuit breakers shall have instantaneous direct acting overcurrent release protection, in accordance with clause 6.4.1 of EN 50123-7-1. This protection directly acts on the circuit breaker and therefore the details of the protection, such as current interruption direction and setting range, shall be in accordance with section 4.3.1. Instantaneous direct acting tripping shall include indication of operation to control systems.

Undervoltage protection

4.2.5.5 Undervoltage protection is used to detect bus faults and other serious faults that cause low voltage on the main DC Traction busbar. The undervoltage protection shall have the following characteristics:

- Maximum input voltage: 1000 V DC;
- Pickup voltage range (adjustable): 400 – 550 V;
- Drop off voltage range (adjustable): 250 – 500 V;
- Drop off time delay range (adjustable): 0 – 1 s (0.050 s maximum step); and
- Accuracy: 0.2% FSD.

Information: Yarra Trams have a preference for the undervoltage protection being indirect acting (using a protection relay) rather than direct acting (using an undervoltage release fitted to the circuit breaker). Therefore, the undervoltage protection function is shown in the protection relay section and is not listed as a mandatory DC circuit breaker release.

Protection relay (indirect acting and high speed tripping)

4.2.5.6 An electronic protection relay shall be provided for each DC Traction circuit breaker.

4.2.5.7 Each protection relay shall be supplied by the Control Voltage. If the relay loses the Control Voltage, the associated circuit breaker shall trip.

4.2.5.8 The protection system shall be failsafe. The failure of any critical device associated with the protection system shall cause the relevant circuit breaker(s) to trip and the system to be placed into a safe state. Device failures include, but are not limited to:

- Internal faults in a protection relay;
- Software glitches in an electronic protection relay;
- Broken leads;
- Transducer or sensor failure;
- Loss of auxiliary control voltage; and
- Indeterminate device operation.

4.2.5.9 The table below lists the minimum protection functions required for the DC Traction protection in accordance with clause 6.5 of EN 50123-7-1. A single-multi function protection relay per circuit breaker is preferred.

Table 2: Typical protection relay functions

Circuit breaker type	Protection requirements
DC Traction rectifier circuit breaker	Instantaneous acting. Undervoltage at rectifier output.
DC Traction feeder circuit breaker	Instantaneous acting. Inverse time for protection of feeder cables and contact lines. Inverse time with thermal time constant. Rate of rise (di/dt). Delta I (ΔI). Instantaneous impedance trip. Intertripping. Cable protection for screened feeder cables. Undervoltage at busbar.
DC Traction circuit breaker	Undervoltage protection

4.2.5.10 All protection elements list in Table 2, except for the thermal protection, shall trip and lock out the relevant DC Traction circuit breaker and require manual investigation and reset. If the thermal protection has operated, the DC Traction circuit breaker shall be prevented from closing until sufficient time has elapsed for the conductor (or equipment) to drop below a predefined temperature limit.

4.2.5.11 The *Scope of Works* will define the need for additional protection relay functions which are not listed in Table 2.

4.2.5.12 The protection relay design life shall be of a minimum of 15 years.

4.2.5.13 The protection relay shall be installed in a manner that will allow upgrade to future generation protection relays with minimal change to the panel it is located in.

Manual / Emergency trip protection

4.2.5.14 All DC Traction circuit breakers shall have a manual trip button. This protection directly acts on the circuit breaker and therefore the details of the protection shall be in accordance with section 4.3.

4.2.5.15 The operation of the manual trip button shall result in a SCADA indication regardless of the status of the supervisory control selector switch.

Frame leakage protection

4.2.5.16 The frames of the DC Traction switchgear cubicles shall be connected to rail earth through a frame leakage relay in accordance with the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2.5.17 In accordance with clause 6.5.7 of EN 50123-7-7, detection of a frame fault shall cause a mass trip of all infeeds to the DC Traction switchgear cubicles to isolate the fault. This shall consider intertripping implementation, therefore, the frame leakage relay shall open a set of contacts and cause the protection to operate, tripping all of the DC Traction switchgear.

4.2.5.18 The protection shall not attempt to reclose automatically in the event of frame leakage (an operator must attend on site to restore power).

4.2.5.19 An indication of the failure shall be provided to the SCADA system.

Information: If the frame of the DC Traction switchgear cubicles is physically, and therefore electrically, connected to the frame of other DC Traction cubicles (e.g. Negative cubicle), then the frame leakage protection of the equipment may be combined. It is common practice to combine the frame leakage protection of the negative cubicle with the DC Traction switchgear cubicles if they are integrated.

External tripping protection

4.2.5.20 The DC Traction rectifier circuit breakers shall allow for at least two external trips to be connected.

Surge protection

4.2.5.21 If adequate surge protection cannot be provided externally, the DC Traction switchgear cubicles shall include suitable surge protection devices to prevent damage to the equipment. If required, these surge protection devices shall be located within the DC Traction switchgear cubicles.

4.2.6 Interlocking

4.2.6.1 The definitions of interlocking are defined in Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2.6.2 In addition to the interlocking requirements outlined in section 6.11 of EN 50123-6, the DC Traction switchgear shall include at least the interlocking outlined in Table 3.

Table 3: Additional interlocking

Interlocking description	Interlocking type	Prerequisite conditions[1]	Notes
Operate short-circuiting switch (DC Traction rectifier breaker)	Mechanical/ Electrical	All of the following: • Respective circuit breaker(s) truck is in the test position; • No voltage detected on the respective DC Traction bus; • Respective negative isolator is in the closed position[2]; • Respective rectifier converter enclosure is closed; and • Respective rectifier transformer enclosure (or separated dedicated room) is closed.	
Operate transfer switch (DC Traction transfer feeder breaker)[3]		• Respective DC Traction transfer feeder circuit breaker is open; and • All other transfer switches are open.	
Operate DC Traction rectifier circuit breaker		All of the following: • Respective circuit breaker(s) truck is in a defined position; • The respective circuit breaker is not tripped and locked out; • Control voltage is available;	

		• Respective negative isolator is in the closed position; • Respective short-circuiting switch is in the open position;	

[1]The order of the prerequisite conditions does not necessarily represent the order of switching operations.

[2]The output terminals of the rectifier converter are only shorted when the respective short-circuiting switch AND negative isolator are closed. If the short-circuiting swich is closed and the negative isolator is open, then the following unsafe condition will be present: The positive terminal of the rectifier converter will be bonded to the negative bus and the negative terminal of the rectifier converter will be floating.

[3]The typical transfer switch operation procedure is outlined in Appendix B9 Transfer and short-circuiting switch operation. Interlocking should prevent more than two transfer switches being closed at any one time (i.e. the transfer panel should only be used to supply the load of a single DC Traction circuit breaker, not multiple DC circuit breakers).

Information: APPENDIX B – EXISTING EQUIPMENT OPERATION AND CONTROL SEQUENCES describes the existing equipment operation and control sequences that are consistent with the existing human interfaces which the Yarra Trams operators are accustomed. This appendix may be used as a reference for the development of additional interlocking principles.

4.2.7 Control panel

4.2.7.1 A control panel shall be provided for each DC circuit breaker panel.

4.2.7.2 Each control panel shall have (where applicable):

- A single control selector switch
- OFF
- LOCAL
- REMOTE
- Push button controls (with anti-knock provision)

Information: Control systems shall be designed to identify different withdrawn position and it shall allow for testing of the breaker based on the position where the panel sits in. When fully withdrawn and disconnected, the breaker shall have ability to be manually closed and latch for maintenance and test maintenance

Table 4: Control push button colour coding

Designation	Colour code
OPEN DCCB	Green
CLOSE DCCB	Red
OPEN TRANSFER SWITCH	Green
CLOSE TRANSFER SWITCH	Red
LAMP TEST	Yellow
FAULT RESET	Blue

Designation	Colour code
TRUCK SOLENOIDE RELEASE	Black
EMERGENCY TRIP	Red
LINE TEST OVERRIDE	Black
UNDERVOLTAGE OVERRIDE	Black

- Indication lamps:

Table 5: Indicator lamp colour coding

Designation	Colour code
DCCB OPEN	Green
DCCB CLOSED	Red
DCCB ISOLATED OR WITHDRAWN	White
DCCB MAGNETIC TRIP	Red
PROTECTION RELAY TRIP	Red
DEVICE FAILURE	Red
EMERGENCY TRIP	Red
LINE TEST FAIL	Red
AUTO RECLOSE DISABLED	White
AUTO RECLOSE IN PROGRESS	White
LOCAL BLOCKING AFTER PROTECTION TRIP	Blue

- Voltmeter, ammeter and associated measurement points (for data acquisition, multimeters, etc.)
- Mimic diagram with associated indicators for the DC circuit breaker and transfer switch
- Associated protection relay

4.2.7.3 In the remote position, SCADA indication of the circuit breaker and transfer switch positions as well as the control sequence (e.g. line test) is returned to the control room. Remote control of the equipment is only available when this switch is in the remote position and the item is in the “IN SERVICE” position.

4.2.7.4 As with protection system, without control voltage, the fail safe condition is that the circuit breaker will trip, while the transfer switch may remain in the latest state prior to loss of control voltage

4.2.7.5 Indication of the most recent trip must be retained until manually reset and must be retained in event recorders

4.2.7.6 Figure 1 represents a typical arrangement for the control panel of the feeder circuit breaker panel (the mimic diagram is not represented). Refer to Scope of Works for specific control panel arrangements and requirements.

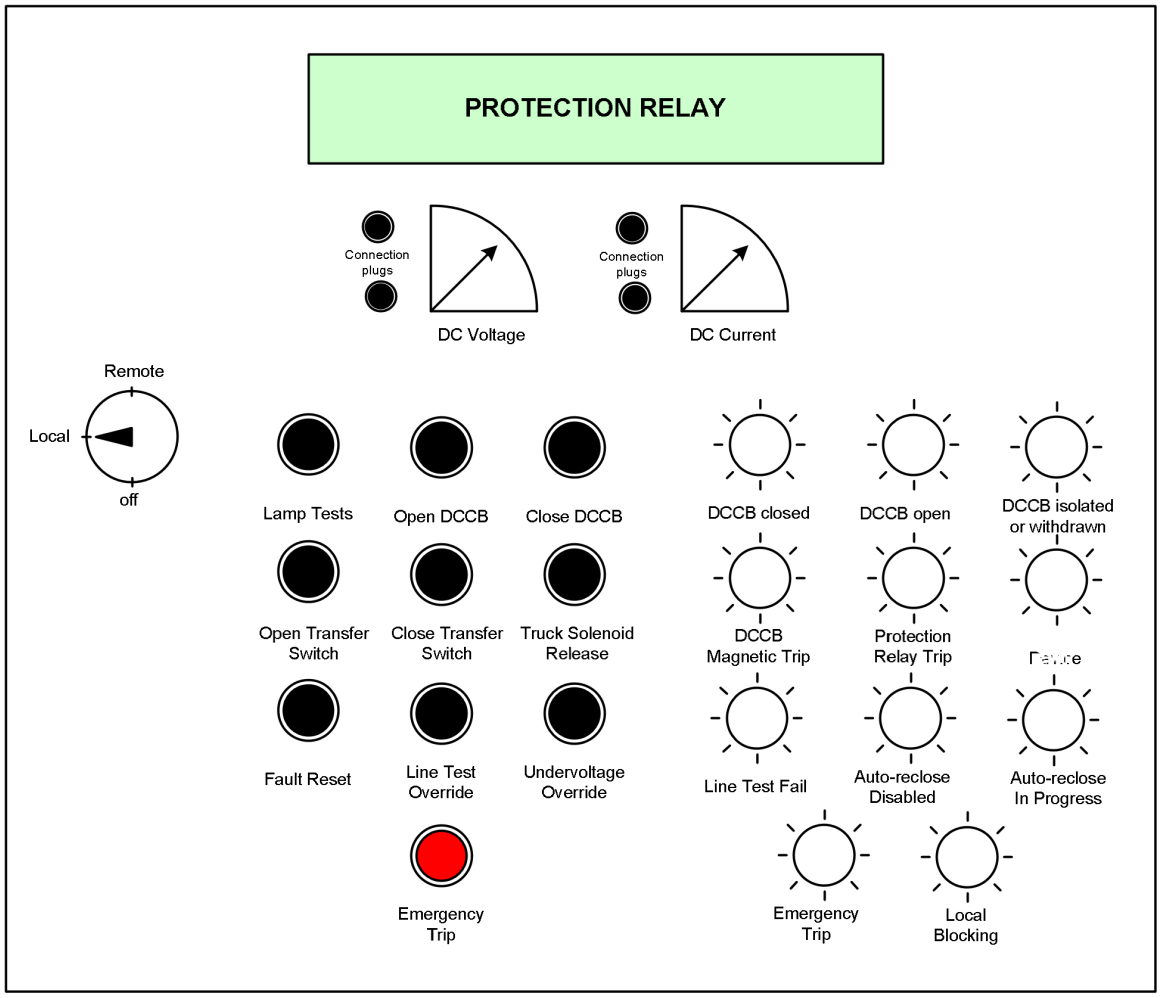

Figure 1: Typical rectifier circuit breaker control panel

4.2.8 Equipment interfaces

SCADA

4.2.8.1 Each indication signal brought back to the SCADA marshalling cubicle shall consist of a pair of voltage free contacts with one normally open and one normally closed. However, it is preferred for the indication signals to be transmitted digitally over a single fibre optic link to reduce the wiring between the control panel and the SCADA marshalling cubicle. Serial communication protocols

such as DNP3.0 would be an advantage for future SCADA expansion on these devices (for the protection relays).

4.2.8.2 The Designer shall ensure that the DC circuit breaker control requirements are compatible with the SCADA output card, located in the SCADA marshalling cubicle.

Power cables

4.2.8.3 Requirements for the power cables are given in the Cable Specification [IN-021-ST-0003].

Control wiring

4.2.8.4 Control wiring shall meet the electromagnetic compatibility requirements defined in section 4.1.4.

4.2.9 Labelling and identification

Warning labels

4.2.9.1 All warning labels shall be in accordance with AS 2067.

Cubicle identification

4.2.9.2 Cubicle identification shall be in accordance with IEC 60445.

4.2.9.3 Additionally, the equipment designations (e.g. DCCB 1) defined in the *Scope of Works* shall be clearly marked.

Terminal marking

4.2.9.4 Terminal marking shall be in accordance with IEC 60445.

Nameplate

4.2.9.5 Each DC circuit breaker panel shall be fitted with a nameplate identifying the entries as per clause 7.2 of BS EN 50123-6. In addition, nameplates for the main items of equipment shall be provided as per clause BS EN 50123-2 and clause 72 of BS EN 50123-3.

4.2.10 Auxiliary and control equipment

4.2.10.1 Voltage free auxiliary contacts shall be provided for use with the substation protection, interlocking and SCADA systems as per section 4.2.8.

4.2.11 Protection relays

4.2.11.1 The protection relays shall comply with the IEC 60255 series.

4.2.11.2 The relay characteristics shall be suitably designed to allow masking of the instantaneous current and voltage spikes that occur when trams pass under section insulators.

4.2.11.3 The input signals to the protection relay shall be provided from a DC shunt or Hall Effect sensor. If a DC shunt is used, then the inputs to the relay shall be insulated from the traction DC voltage via an isolating transducer which conforms to the DC Traction Transducer and Measurement Device Specification [IN-021-ST-0014]. No hazardous voltages shall be transferred to personnel or equipment that are in contact with the protection relay.

4.2.11.4 Electronic protection relays shall maintain an event log of all protection trips. The relay shall maintain a minimum of 100 protection events in memory which are downloadable via SCADA or to a PC. It is preferable that the event timestamp is obtained from a central clock (e.g. GPS timestamp or SCADA clock) rather than an individual onboard clock.

4.2.11.5 For electronic protection relays, in addition to the event log, the waveform that caused the protection to operate shall be stored for at least the last 5 protection events. The waveform data shall consist of a minimum of 250 measurements at a sampling frequency of 1 kHz. (The preference is at least 2000 samples at greater than 4 kHz.)

4.2.11.6 PC interface software shall be provided for electronic protection relays. As a minimum, this software shall allow the user to download event logs and waveforms, inspect the health of the relay and upload new protection settings.

4.2.11.7 The protection relay shall be installed in such a way that future upgrades to the device can be carried out without major modifications.

4.2.12 Transducers and measurement devices

4.2.12.1 Sensors and transducers shall be provided to monitor the following:

- Rectifier circuit breaker: DC bus voltage;
- Feeder circuit breaker: DC output voltage and DC current (input or output); and
- Bus-tie circuit breaker: DC voltage on both sides and DC current (on one side only).

4.2.12.2 Provision shall be made to gain ready access to the terminals for the purpose of connecting load-recording instruments.

4.2.12.3 These measurements shall be available for the SCADA system. This can require two independent outputs per transducer or two different transducers per signal (one for the measurement / instrumentation within the substation and the other for the SCADA system). Transducers for protection purposes shall be separate.

4.2.12.4 The wiring from the sensors to the transducers shall be suitably insulated from the main circuit and meet the electromagnetic compatibility requirements of section 4.1.4.

4.2.12.5 Requirements for the sensors and transducers are given in the DC Traction Transducer and Measurement Device Specification [IN-021-ST-0014].

4.2.13 Line test devices

4.2.13.1 Line test devices, including auto-reclose sequence, shall be provided for each feeder circuit breaker.

4.2.13.2 Line test devices shall also be provided for bus-tie circuit breakers. However, these devices will test the bus on either side before closing, not the overhead line.

4.2.13.3 These devices shall be compliant with clause 5.4 of BS EN 50123-7-1. The basic circuit for the line test device is set out in clause 5.4 of BS EN 50123-7-1 (Figure 2). The line test will enable the functional re-close operation of each feeder panel and must be clearly determined by the protection engineer in-charge, and based on a safety risk assessment of the electrical systems.

4.2.13.4 Line test and auto-reclose shall be designed in accordance with clause 11.3 of EN 50388.

4.2.13.5 The line test current shall be configurable.

4.2.13.6 Low resistance fuses shall be used to prevent false readings and failure of any fuses shall not give a false reading.

4.2.13.7 When the panel is in REMOTE mode, the SCADA shall be notified of each line test that is performed and its final result. The SCADA system shall capture each change of state.

4.2.13.8 The feeder panel shall reclose without the need for line test when adequate voltage is sensed on the outgoing overhead section. This voltage should be adjustable between 400 and 600/750 V DC. The DC Traction undervoltage trip level identified above and the voltage sense reclose level may differ.

4.2.13.9 It shall be possible to disable the Line Test and Automatic Reclose system remotely via a SCADA control which presets the condition, “AUTO RECLOSE DISABLED”. In this mode the feeder panel will not attempt to reclose following any protection system trip until a new SCADA “remote” close control command is initiated for each and every trip. The reclosing test feature of the circuit shall operate normally under these circumstances.

4.2.13.10 The following table outlines the minimum requirements for the line test circuit operation

Table 6: technical requirements for the line test circuit time delays and operations

Description	Requirements
Time delay to first reclose	15 second nominal (adjustable between 5 and 30 seconds)
Time delay between tests and reclose	15 seconds nominal (adjustable between 5 and 30 seconds)
Number of tests before blocking	3 nominal (adjustable between 1 and 3

4.3 DC Traction circuit breakers

4.3.1 General

4.3.1.1 Each DC circuit breaker shall be a Secheron UR26.

4.3.1.2 Three types of DC circuit breaker are defined as follows:

- Rectifier circuit breakers (use R – unidirectional U, fitted with a series unidirectional release U1)
- Feeder circuit breakers (use L – unidirectional U, fitted with a series bidirectional release U2); and
- Bus-tie circuit breakers (use I – bidirectional B).

4.3.1.3 Each DC circuit breaker shall be electrically operated and held closed by an electro-mechanical latch.

4.3.1.4 Interlocking requirements are defined in 4.2.6.

4.3.1.5 The DC circuit breakers shall have the following ratings, in addition to the requirements defined in section 4.2.1:

Table 7: DC circuit breaker ratings

Characteristic	Rating
Rated maximum arc voltage	2000 V DC (to be confirmed by the Designer)
Rated service current for the main circuit (INE)	For rectifier circuit breakers: Identical to the continuous rated current of the associated rectifier converter (refer to X) For feeder circuit breakers: 2000 A DC (to be confirmed by the Designer)
Conventional thermal current (Ith, Ithe)	Identical to rated service current
Rated short-circuit making capacity	1.42 x rated short-circuit current (INSS) (to be confirmed by the Designer)
Rated short-circuit breaking capacity	70 kA with a 10 ms time constant (to be confirmed by the Designer)
Rated short-time withstand current (INCW)	30 kA for a period of 250 ms (to be confirmed by the Designer)
Overload capability (for rectifier and bus-tie circuit breakers only)	100% continuously 150% 2 hours 300% 1 minute
Duty cycle	In accordance with clause 5.3.4.2 of BS EN 50123-2 (Tables 2 and 3)

4.3.1.6 The Designer is fully responsible for providing suitable ratings for the DC circuit breakers and shall therefore verify the above values.

4.3.1.7 In accordance with clause 5.1.1.5 of BS EN 50123-1, the rated service current of the rectifier or bus-tie circuit breaker shall meet the overload requirements of the rectifier converter.

4.3.2 Trip direction

4.3.2.1 Rectifier circuit breakers trip circuit should be directional looking in the reverse direction.

4.3.2.2 Feeder circuit breakers trip circuit should be bi-directional looking in both directions. Bi-directional feeder circuit breakers are acceptable because the fault level in the reverse direction should be much lower than in the forward direction.

4.3.2.3 Bus-tie circuit breakers trip circuit should be bi-directional.

4.3.3 Auxiliary contacts and circuits

4.3.3.1 Auxiliary circuits shall be in accordance with clause 5.5 of BS EN 50123-2.

4.3.3.2 The minimum number of auxiliary contacts required is 5 X Normally Open (NO) and 5 X Normally Closed (NC).

4.3.4 Type of release

4.3.4.1 The DC Traction circuit breakers shall include the following releases:

- Direct overcurrent release and;
- Manual release.

4.3.5 Materials

4.3.5.1 In accordance with clause 6.1.1 of BS-EN 50123-2, no materials containing asbestos shall be used in the construction of the circuit breaker. Special attention is to be paid to the ability of the material used 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 minimized.

4.3.6 Arcing contacts

4.3.6.1 As per clause 6.1.2 of BS EN 50123-2, arcing contacts shall be easy to replace.

4.3.6.2 When replacing Arc Chutes the circuit breaker shall be designed to prevent energization in the case that the arc chute is not fastened down securely or attached correctly

4.3.7 Primary connections

4.3.7.1 As per clause 6.1.4 of BS EN 50123-2 and clause 6.3 of BS EN 50123-6, the withdrawable functional units shall be equipped with plug-in connectors.

4.3.8 Manual operation

4.3.8.1 Provision for manual operation shall be made. As per clause 6.1.7 of BS EN 50123-2, it shall not be possible to operate the circuit breaker manually unless it is fully withdrawn (refer to Appendix B).

4.3.9 Trip counter

4.3.9.1 Every trip on the DC circuit breakers shall be recorded by means of an electro-mechanical non-resettable counter.

Instantaneous direct acting overcurrent protection with adjustable setting range

4.3.9.2 In accordance with clause 6.4.1 of EN 50123-7-1, the setting range for the direct overcurrent release shall be 2,000 A – 6,000 A minimum and 2,000 A – 8,000 A preferred. This range shall be adjustable by a single calibrated knob, and calibrated so that an adequate number of current setting steps are provided. The accuracy of the markings shall be less than +10%. Only one adjustment mechanism or arm shall be provided. This arm shall be locked to prevent inadvertent movement. Setting points shall be clear marked in a readable and permanent fashion.

Manual / **Emergency trip protection**

4.3.9.3 Manual tripping of each circuit breaker shall be provided by a manual trip button. The manual tripping button shall operate directly off the mechanical latching mechanism and shall not rely on electrical shunt tripping. The operation of the manual trip system shall prevent the DC circuit breaker from automatically electrically reclosing until a local manual reset occurs. A separate electrical limit switch shall be provided on the manual trip circuit to indicate to the feeder panel control circuit that an Emergency Trip has occurred.

4.3.9.4 Emergency tripping shall be achieved without the need for undue force on the trip mechanism.

4.4 Transfer switches

4.4.1 General

4.4.1.1 A transfer switch shall be provided for each feeder circuit breaker and fitted in the associated panel.

4.4.1.2 The transfer switch shall be load make and break type, single-pole, electrically operated, mounted on a withdrawable truck and compliant with BS EN 50123-3.

4.4.1.3 Interlocking requirements are defined in section 4.2.6. A padlock mechanism shall be provided for lock out.

4.4.1.4 The transfer switches shall have the following ratings:

Table 8: Transfer switch characteristics

Characteristic	Rating
Class of use	Minimum Category III
Rated service current for the main circuit (INE)	Identical to the associated feeder circuit breaker
Conventional thermal current (Ith, Ithe)	Identical to rated service current
Rated making capacity	INE
Short-time withstand current	Identical to the associated feeder circuit breaker
Overload capability	110% continuously

4.4.1.5 The Designer is fully responsible for providing suitable ratings for the transfer switches and shall therefore verify the above values.

4.4.2 Auxiliary contacts and circuits

4.4.2.1 Auxiliary circuits shall be in accordance with clause 5.6 and 6.11 of BS EN 50123-3.

4.4.2.2 The minimum number of auxiliary contacts required is 5 X Normally Open (NO) and 5 X Normally Closed (NC).

4.4.3 Materials

4.4.3.1 In accordance with clause 6.1.1 of BS EN 50123-3, no materials containing asbestos shall be used in the construction of the switch or disconnector. Special attention is to be paid to the ability of the

material used 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.

4.4.4 Arcing contacts

4.4.4.1 As per clause 6.1.2 of BS EN 50123-3, arcing contacts (if any) shall be easy to replace.

4.4.5 Primary connections

4.4.5.1 As per clause 6.1.4 of BS EN 50123-3 and clause 6.3 of BS EN 50123-6, the withdrawable functional units shall be equipped with plug-in connectors.

4.4.6 Manual operation

4.4.6.1 As per clause 6.1.7 of BS EN 50123-3, all units shall be provided with a manual closing handle or service, emergency and/or maintenance use.

4.4.7 Operation counter

4.4.7.1 Every operation on the transfer switches shall be recorded by means of an electro-mechanical nonresettable counter.

4.4.7.2 Fault levels shall consider interlocking to ensure that no more than one transfer switch and one Auxiliary Panel can be closed at the same time.

4.5 Short circuiting switches

4.5.1 General

4.5.1.1 A short-circuiting switch shall be provided for each feeder circuit breaker and fitted in the associated panel. However, there is an option to provide this in the isolator cubicle

4.5.1.2 The short-circuiting switch shall be load make type, single-pole, manually operated and compliant with BS EN 50123-3.

4.5.1.3 A failsafe voltage sensing device designed to measure the voltage on the outgoing cable(s) shall be provided.

4.5.1.4 The switch must be designed and mounted in such a manner as to prevent injury to the operator should the switch be closed on to a live circuit.

4.5.1.5 Where applicable, operation of the switch should be from the front panel of the feeder panel to prevent any confusion when short-circuiting.

4.5.1.6 Interlocking requirements are defined in Section 4.2.6. A padlock mechanism shall be provided.

4.5.1.7 Securely protected access shall also be provided to the main DC bus and outgoing feeder flag for the purpose of performing a manual test of the flag status prior to short circuiting should this be necessary.

4.5.1.8 The short-circuiting switches shall have the following ratings, in addition to the requirements defined in section 4.2.1:

Table 9: Short circuit switch ratings

Characteristic	Rating
Class of use	Category VI
Rated service current for the main circuit (INE)	Identical to the associated feeder circuit breaker (to be confirmed by the Designer)
Conventional thermal current (Ith, Ithe)	Identical to rated service current
Rated making capacity	INSS
Rated breaking capacity	3 x INE
Short-time withstand current	Identical to the associated feeder circuit breaker (to be confirmed by the Designer)

4.5.1.9 The Designer is fully responsible for providing suitable ratings for the short-circuiting switches and shall therefore verify the above values.

Arc fault pressure relief flaps and gas exhaust ducts

4.5.1.10 The DC Traction switchgear shall be designed to contain any arc faults within its cubicle. If this is not possible, then any arc fault pressure relief flaps and gas exhaust ducts shall be designed.

4.5.1.11 The arc fault pressure relief flaps and gas exhaust ducts should vent to outside of the building to a safe space, rather than into the room itself.

4.5.2 Auxiliary contacts and circuits

4.5.2.1 Auxiliary circuits shall be in accordance with clause 5.6 and 6.11 of BS EN 50123-3.

4.5.2.2 The minimum number of auxiliary contacts required is 5 X Normally Open (NO) and 5 X Normally Closed (NC).

4.5.3 Materials

4.5.3.1 In accordance with clause 6.1.1 of BS EN 50123-3, no materials containing asbestos shall be used in the construction of the switch or disconnector. Special attention is to be paid to the ability of the material used 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.

4.5.4 Arcing contacts

4.5.4.1 As per clause 6.1.2 of BS EN 50123-3, arcing contacts (if any) shall be easy to replace.

4.5.5 Primary connections

4.5.5.1 As per clause 6.1.4 of BS EN 50123-3, the short-circuiting switches shall be equipped with fixed connections.

4.5.5.2 An inspection window for the short circuiting switch shall be provided to enable the visual inspection of the device position in either position.

4.5.5.3 Primary connections shall not be accessible without removing the cover by using tools.

4.5.6 Manual operation

4.5.6.1 As per clause 6.1.7 of BS EN 50123-3, all units shall be provided with a manual closing handle or service, emergency and/or maintenance use.

4.6 Testing

4.6.1.1 The Factory Acceptance Tests shall be compliant with the relevant parts of BS EN 50123-1, BS EN 50123-2, BS EN 50123-3 and BS EN 50123-6.

4.6.1.2 Only Type Tested panels will be accepted, Type tests shall be provided for the DC Traction switchgear and controlgear

4.6.1.3 Test certificates to demonstrate high reliability of the mimics over thousands of operations shall be supplied.

4.6.1.4 In addition to the above requirements, routine tests shall be carried out to verify all control sequences and interlocks specified in this document.

4.7 Reliability, Availability, Maintainability and Safety (RAMS)

4.7.1.1 The RAMS requirements shall be those defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.8 Documentation

4.8.1.1 Submitted documentation shall at least comprise the items outlined in Table 10. This documentation shall be provided for the DC Traction Switchgear and Controlgear throughout the procedure outlined in EMS Design Acceptance Standard [CE-023-ST-0020].

4.8.1.2 RAMS design report must also be provided outlining how feeder panels operate independently and identifying all sources of equipment failure that may result in simultaneous loss of two or more feeder panels.

Table 10: Documentation

Documentation	Step 1: System Design Specifications (SDS)	Step 2: Acceptance Test Criteria	Step 3: Preliminary Design	Step 4: Detailed Design	Step 5: Production	Step 6. Installation/Site Assembly	Project completion
Statement of compliance			✓				
Technical specification			✓				
Single-line diagram of main circuit			✓				
General layout			✓				
Detailed drawings of electrical circuits (main and auxiliary)				✓	✓	✓	✓[1]
Detailed drawings of mechanisms				✓	✓	✓	✓[1]

Documentation	Step 1: System Design Specifications (SDS)	Step 2: Acceptance Test Criteria	Step 3: Preliminary Design	Step 4: Detailed Design	Step 5: Production	Step 6. Installation/Site Assembly	Project completion
Detailed drawings of mechanical arrangement, including cable boxes				✓	✓	✓	✓[1]
Connection guide (conductors, earthing, auxiliary circuits, etc)			✓	✓	✓	✓	✓[1]
Bill of materials				✓	✓	✓	✓[1]
Detailed drawing of nameplate					✓	✓	✓[1]
Type test certificates					✓	✓	✓
Test reports					✓	✓	✓
Installation manual(s)			✓[2]		✓	✓	✓
Operation manual(s)			✓[2]		✓	✓	✓
Maintenance manual(s)			✓[2]		✓	✓	✓
List of recommended spare parts and their availabilities			✓[2]		✓	✓	✓
PLC ladder diagrams and software (if applicable)							✓

[1]Drawings shall be submitted into PTV's Drawing Management System Compliant library according to the requirements of clause 4.5.1.2.

[2]Only typical non-project specific documentation required.

4.8.1.3 The documentation shall be compliant with the requirements defined in Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

5 DIAGRAMS AND GUIDANCE

5.1 Equipment layout

5.1.1.1 The circuit breaker panels shall be arranged side by side as a single assembly with continuous busbars. The preferred arrangements are shown in Figures 2, 3 and 4. The following definitions apply in the figures:

- L = Line circuit breaker (Yarra Trams terminology = Feeder circuit breaker);
- R = Rectifier circuit breaker;
- I = Interconnecting circuit breaker (Yarra Trams terminology = Bus-tie circuit breaker); and
- Grey = optional

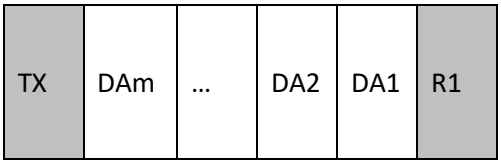

Figure 2: Single rectifier substation – Preferred arrangement

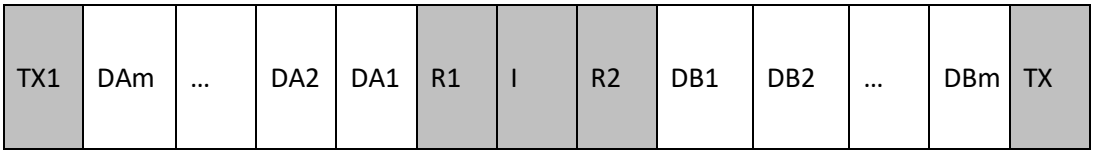

Figure 3: Dual rectifier substation (with optional split bus) – Preferred arrangement

Figure 4: Dual rectifier substation (with optional split bus) – Alternative arrangement

6 RELATED LEGISLATION & DOCUMENTS

6.1.1.1 The design and construction of DC Traction switchgear and controlgear is to be consistent with the best engineering practices and shall comply with all of the referenced documents listed in this section. These referenced documents shall be read in conjunction with this specification.

6.1.1.2 All referenced documents shall refer to the most recent published versions of them at the time of invitation to tender.

6.1.1.3 Wherever a conflict exists in the requirements of these documents, the order of precedence shall be observed as defined in Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

Table 11: Referenced documents

Name	Document number
Yarra Trams	
Infrastructure - Network Power – Substation Design and Construction	CE-021-ST-0023
Infrastructure - Network Power – Traction Power – Design and Construction	CE-021-ST-0037
DC Traction Transducer and Measurement Device	IN-021-ST-0014
Cable Specification	IN-021-ST-0003
Public Transport of Victoria	
PTV Infrastructure Drafting Standards	
PTV NTS Standards	
Traction Power Systems Standard	PTV-NTS-004
Regulations & other legislative documents	
As defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023]	
Industry codes of practice, guidelines, policies, and rules	
As defined in the Infrastructure - Network Power – Traction Power – Design and Construction [CE-021-ST-0037]	
Australian Standards	
Maintenance of electrical switchgear	AS 2467
Common specifications for high-voltage switchgear and controlgear standards	AS 2650
Degrees of protection provided by enclosures (IP Code)	AS 60529
International Standards	
Railway applications – Fixed installations – D.C. switchgear – Part 1:	BS EN 50123-1
Railway applications – Fixed installations – D.C. switchgear – Part 2: D.C. circuit breakers	BS EN 50123-2

Railway applications – Fixed installations – D.C. switchgear – Part 3: Indoor d.c. disconnectors, switch-disconnectors, and earthing switches	BS EN 50123-3
Railway applications – Fixed installations – D.C. switchgear – Part 6: D.C. switchgear assemblies	BS EN 50123-6
Railway applications – Fixed installations – D.C. switchgear – Part 7-1: Measurement, control, and protection devices for specific use in d.c. traction systems – Measurement, control, and protection devices for specific use in d.c. traction systems – Application guide	BS EN 50123-7-1
Basic and Safety Principles for Man-Machine Interface, Marking and Identification – Identification of Equipment Terminals, Conductor Terminations and Conductors	IEC 60445
Railway Applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability	EN 50388

DOCUMENT VERSION CONTROL

Table 12: Document version control

Version History	Date	Detail
1.0	3/08/2021	Original approved issue
1.06	12/05/2025	Authorisor Update
1.07	10/03/2026	Periodic review. No change
1.08	24/06/2026	Changed from Standard to specification. Document number changed from CE-019-ST-0048 to CE-019-SP-0048 and changed the YJM logo.

APPENDIX A – DEFINITIONS & ABBREVIATIONS

Table 13: Glossary - Words

Word	Definition
Control Voltage	Supply voltage of closing and opening devices and of auxiliary and control circuits as defined in Tram Traction Substation – General Design Requirements [PSU-2.6-SPA-0001]
De-energised	Electrical equipment that has had its electrical energy source removed is de-energised.
Energised	Equipment that is electrified by an electrical energy source is energised.
Racked-in	When a circuit breaker has been placed into position and is ready to be energised it is considered Racked-in.
Racked-out	When a circuit breaker has been de-energised and physically removed from being able to be energised it is considered Racked-out.

Word	Definition
Scope of Works	The Scope of Works is a key document that defines the specific project-related requirements such as the configuration and rating of equipment to be installed. It prevails over all the specifications

Table 14: Glossary - Abbreviations

Abbreviation	Definition
AC	Alternating Current
DC	Direct Current
DCCB	DC Circuit Breaker
EMC	Electromagnetic Compatibility
FAT	Factory Acceptance Test
FSD	Full Scale Deflection
HV	“High Voltage” means a nominal voltage exceeding 1000 V AC or exceeding 1500 V DC
LV	“Low Voltage” means nominal voltage exceeding 50 V AC / 120 V DC but not exceeding 1000 V AC / 1500 V DC
RMS	Root Mean Square

APPENDIX B – TENDER REQUIREMENTS

Table 15 summarises the information which shall be defined by Yarra Trams in the *Scope of* Works at the time of tender.

Table 15: Summary of information to be defined in the Scope of Works

Description	Requirement
Equipment designation	

Statement of compliance

The *Designer* shall return a clause by clause statement of compliance to this specification. The Yarra Trams statement of compliance template and deviation procedure for specifications is provided within the Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

Equipment selection principles

The equipment selection principles are defined in Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

APPENDIX B – EXISTING EQUIPMENT OPERATION AND CONTROL SEQUENCES

B1 General

This appendix describes the existing equipment operation and control sequences that are consistent with the existing human interfaces with which the Yarra Trams operators are accustomed. However, they are not intended to be prescriptive for the control logic design.

The use of the terms 'shall' and 'should' in this appendix only apply if the *Designer* plans to follow the existing equipment operation and control sequences. This appendix is only for informative purposes so that the *Designer* may understand the existing/typical Yarra Trams equipment operation and control sequences. This appendix does not contain requirements in the context of compliance with this specification.

B2 Selector switch operation

Off mode

Figure 5 illustrates the desired control sequence for operation of the selector switch to the OFF position. This diagram is indicative only and outlines the main control sequence requirements. When the selector switch is turned to the OFF position:

- The DCCB shall trip immediately;
- Local control of the panel shall be disabled;
- Remote control of the panel shall be disabled;
- Indication of equipment status via SCADA shall be disabled; and
- The truck solenoid release pushbutton shall be enabled.

NOTE: If the control voltage is not available or the umbilical cord is disconnected, the operation of the selector switch to the OFF position shall have no effect.

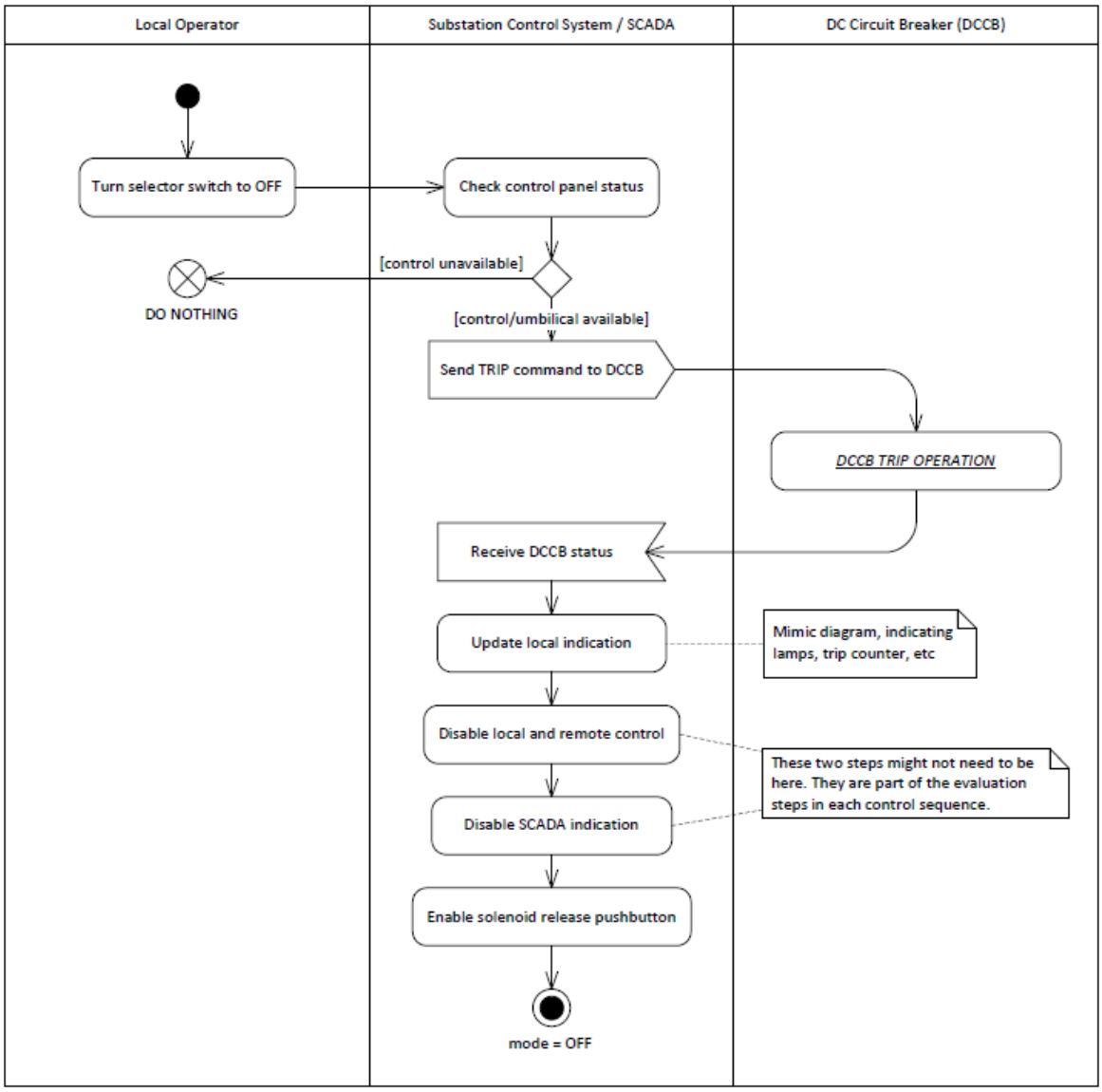

Figure 1: Operation of the selector switch to the OFF position

Local mode

Figure 6 illustrates the desired control sequence for operation of the selector switch to the LOCAL position. This diagram is indicative only and outlines the main control sequence requirements. When the selector switch is turned to the LOCAL position:

- Local control of the panel shall be enabled;
- Remote control of the equipment shall be disabled, and the control room notified;
- Indication of equipment status via SCADA shall be disabled; and
- The truck solenoid release pushbutton shall be disabled.

NOTE: If the control voltage is not available or the umbilical cord is disconnected, the operation of the selector switch shall have no effect.

If the circuit breaker truck handle is in an intermediate position (i.e. not IN SERVICE or ISOLATED) the truck solenoid will be unlocked. In this situation, although the switch might be in the LOCAL position, the panel shall not enter the LOCAL mode of operation until the handle reaches its destination and the truck solenoid is locked (re-engaged).

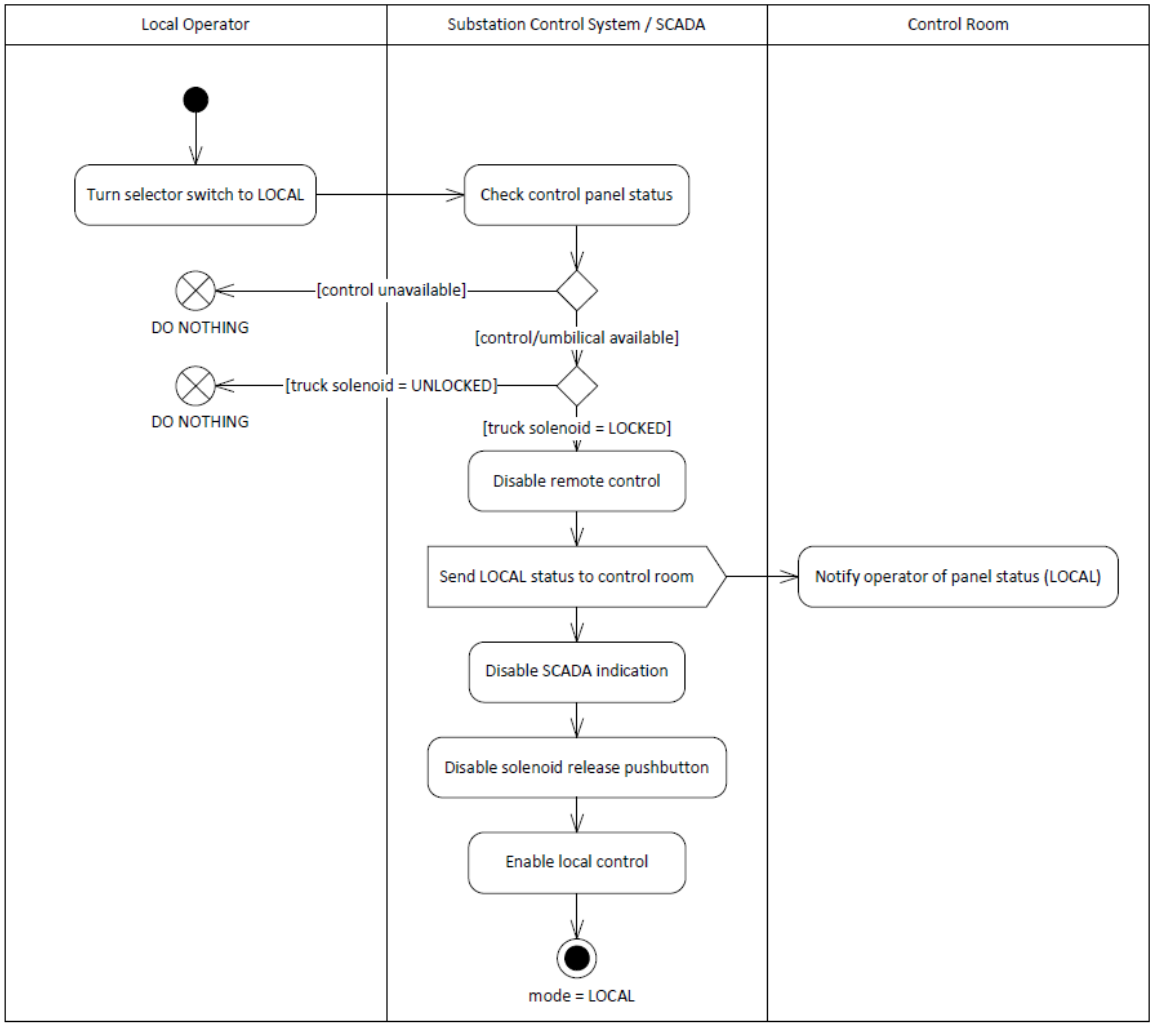

Figure 6: Operation of the selector switch to the LOCAL position

Remote mode

Figure 7 illustrates the desired control sequence for operation of the selector switch to the REMOTE position. This diagram is indicative only and outlines the main control sequence requirements. When the selector switch is turned to the REMOTE position:

- Local control of the panel shall be disabled;
- Remote control of the panel shall be enabled, and the control room notified;
- Indication of equipment status via SCADA shall be enabled; and
- The truck solenoid release pushbutton shall be disabled.

NOTE: If the control voltage is not available or the umbilical cord is disconnected, the operation of the selector switch shall have no effect.

If the circuit breaker truck handle is in an intermediate position (i.e. not IN SERVICE or ISOLATED) the truck solenoid will be unlocked. In this situation, although the switch might be in the REMOTE position, the panel shall not enter the REMOTE mode of operation until the handle reaches its destination and the truck solenoid is locked (re-engaged).

Although the panel might be in REMOTE mode, there may be additional conditions that must be satisfied before certain equipment can be operated remotely (e.g. circuit breaker truck must also be IN SERVICE before it can be operated remotely). These additional constraints are detailed in the various remote control sequences contained in this section.

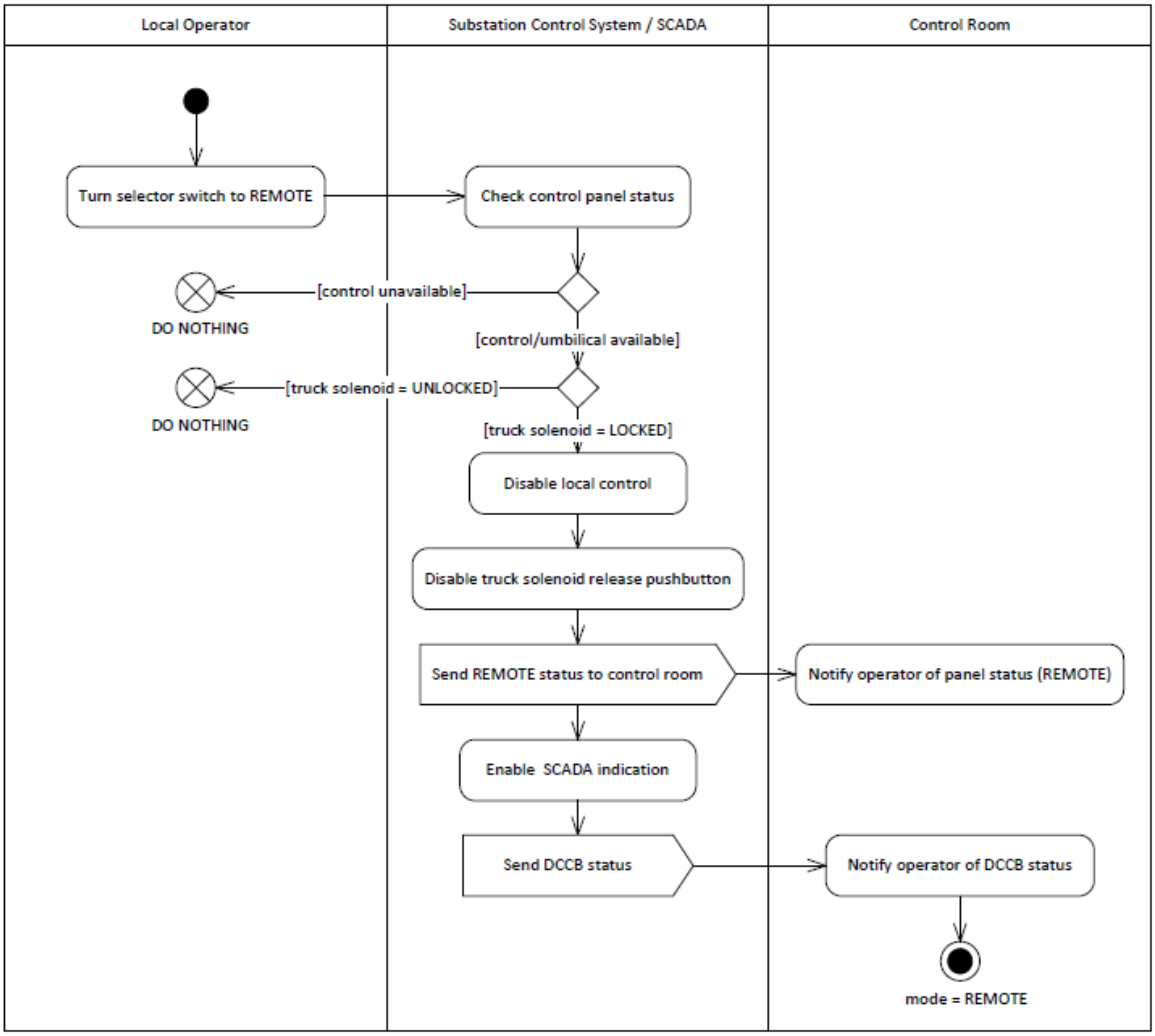

Figure 7: Operation of the selector switch to the REMOTE position

B3 DC Traction circuit breaker truck operation

Truck handle and solenoid operation

The DC Traction circuit breaker truck handle shall have two positions:

- IN SERVICE; and
- ISOLATED.

The truck handle shall be electrically locked in position by a solenoid. The solenoid shall be unlocked by pressing and holding a pushbutton control on the control panel. The pushbutton control (and solenoid) shall only be operable when the following conditions are met:

- Umbilical cord is connected and the control voltage is available;
- The control panel is in the OFF mode; and
- The handle is in a definite position.

Once the solenoid has been unlocked and the operating handle is in an intermediate position, the solenoid shall be prevented from being locked until the handle reaches its destination. Manual operation of the solenoid or bypassing of the interlocks (e.g. forcing the operating handle) shall trip the circuit breaker.

DC Traction circuit breaker withdrawal sequence

Figure 8 illustrates the desired control sequence for withdrawing the DC Traction circuit breaker. This diagram is indicative only and outlines the main control sequence requirements.

It shall not be possible to ISOLATE the circuit breaker unless the panel is in the OFF mode (which means that the circuit breaker will be OPEN). When the panel is in OFF mode, the operator can press and hold the solenoid pushbutton to unlock the operating handle. Once the operating handle has been moved from the IN SERVICE position, it cannot be locked again until the handle reaches its destination or is returned to the IN SERVICE position.

When the circuit breaker truck is in the IN SERVICE position, movement of the operating handle from IN SERVICE to ISOLATED shall withdraw the circuit breaker truck and disengage the primary contacts from the main bus. When both the handle and the truck have reached their respective ISOLATED positions, if the solenoid pushbutton is released, the operating handle shall be locked again, and the selector switch may be turned to LOCAL or REMOTE for testing.

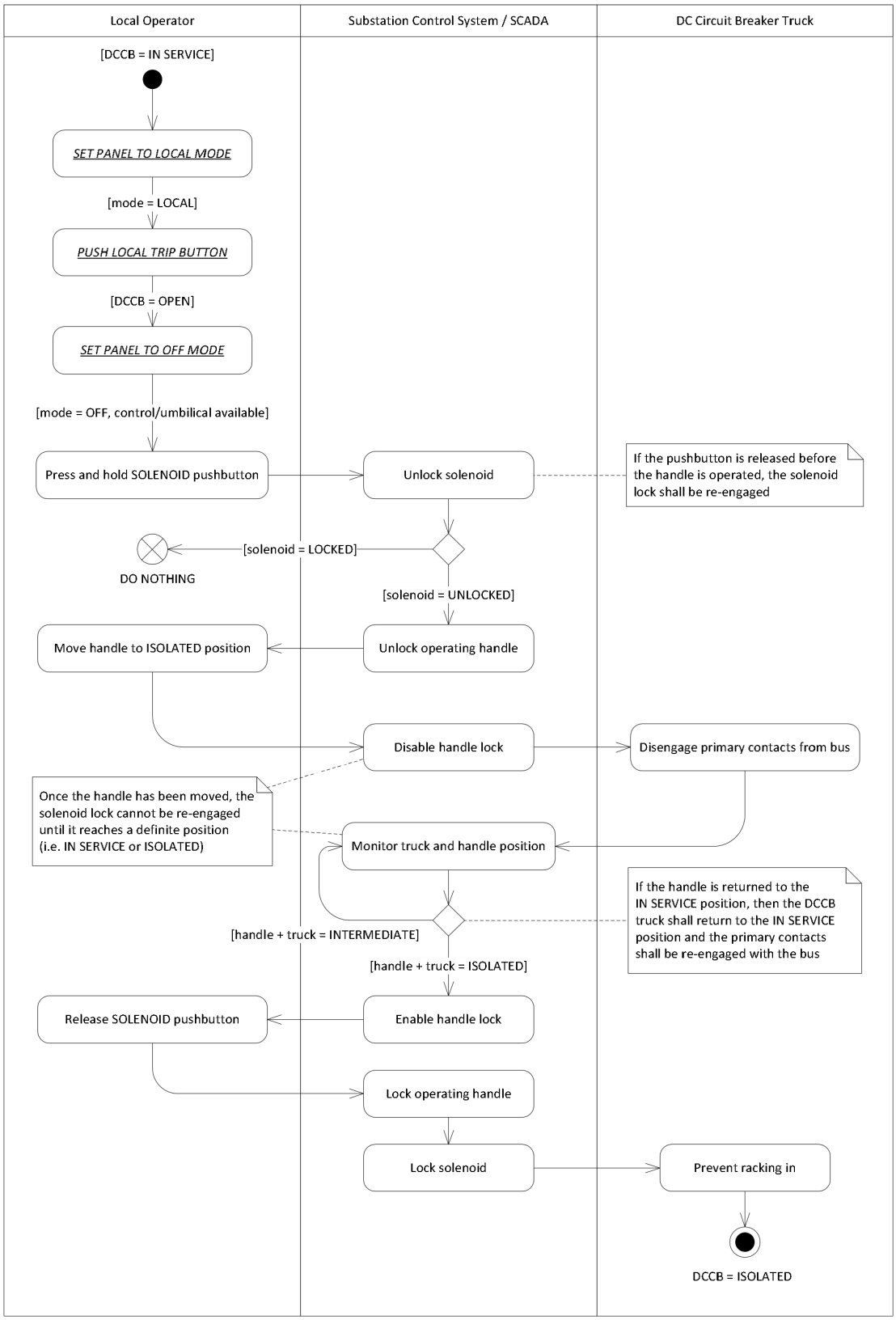

Figure 8: DC Traction circuit breaker withdrawal sequence

DC Traction circuit breaker insertion sequence

Figure 9 illustrates the desired control sequence for inserting the DC Traction circuit breaker. This diagram is indicative only and outlines the main control sequence requirements.

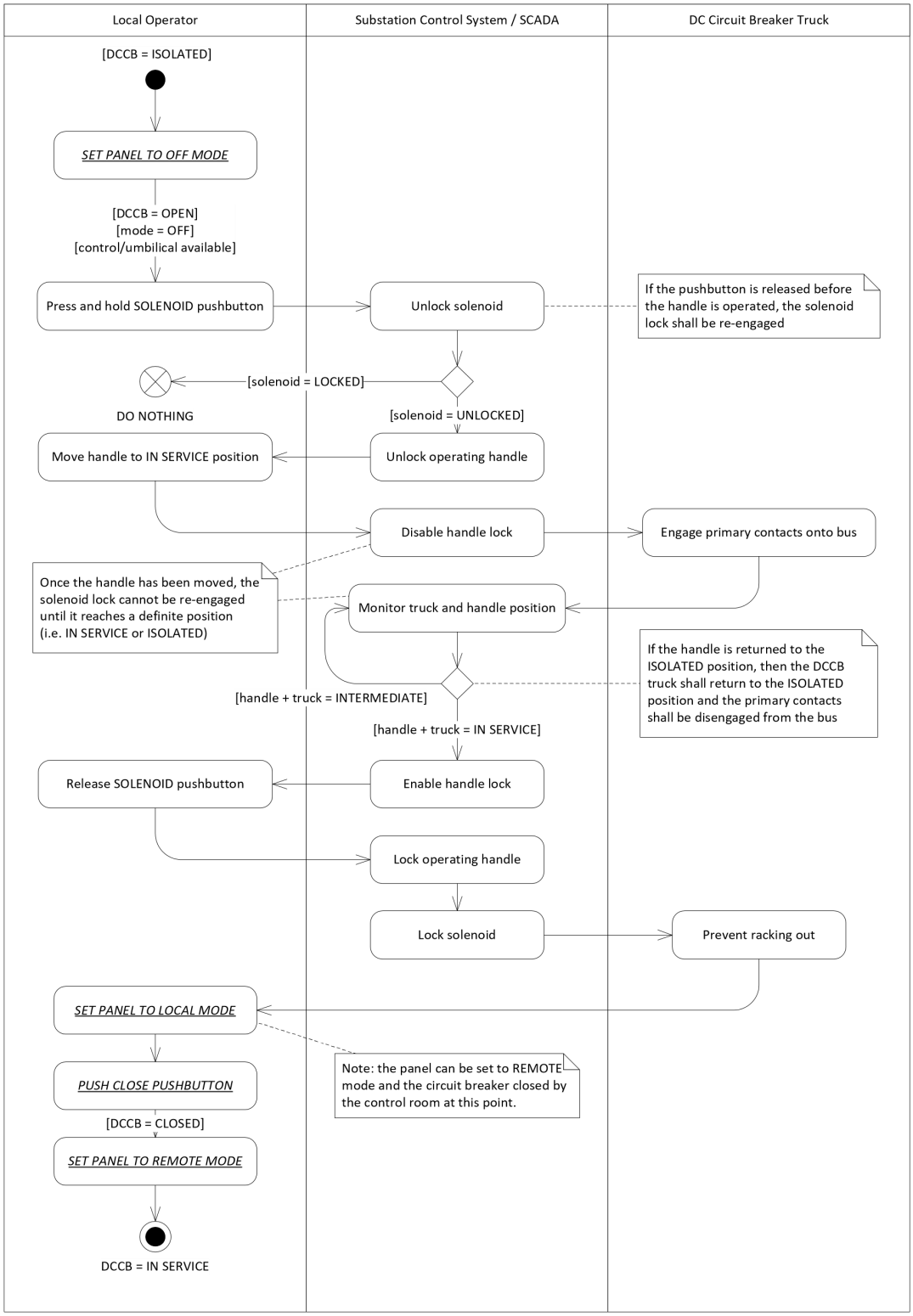

Figure 9: DC Traction circuit breaker insertion sequence

B4 DC Traction circuit breaker operation: Close

Local close operation

Figure 10 illustrates the desired control sequence for locally closing the DC Traction circuit breaker.

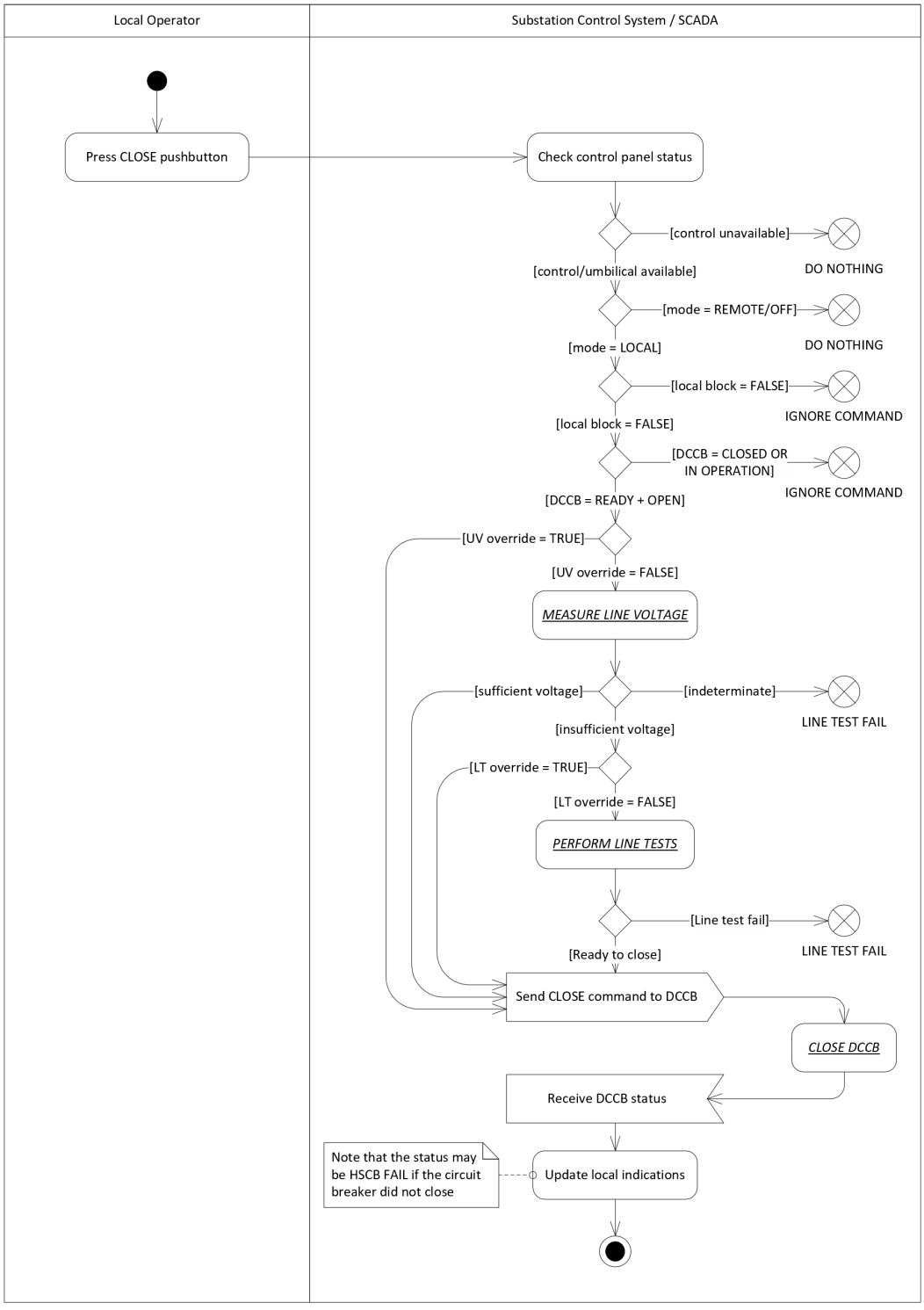

Figure 10: DC Traction circuit breaker local close operation

Remote close operation

Figure 11 illustrates the desired control sequence for remotely closing the DC Traction circuit breaker.

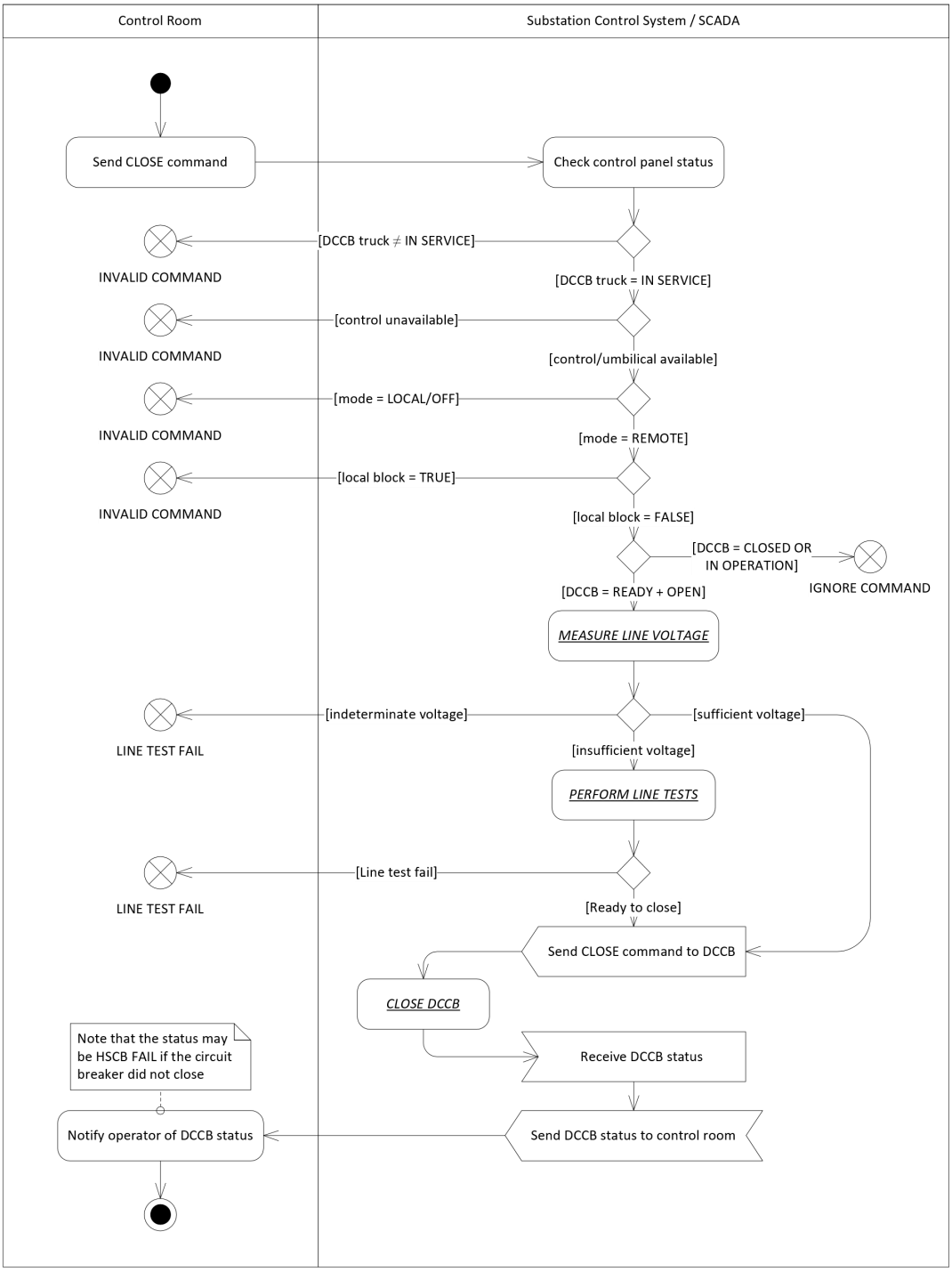

Figure 11: DC Traction circuit breaker remote close operation

Circuit breaker close operation

Figure 12 illustrates the desired control sequence for closing the DC Traction circuit breaker.

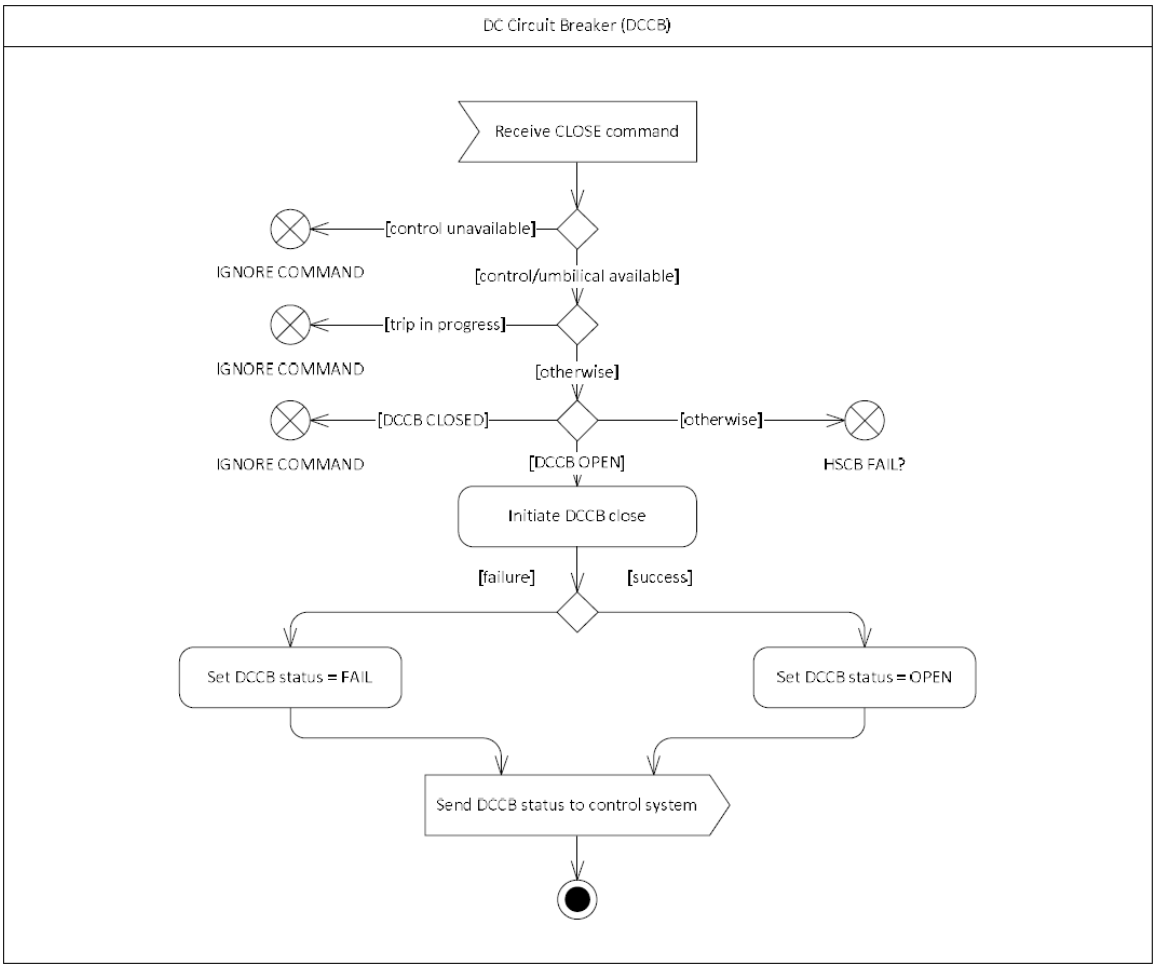

Figure 12: DC Traction circuit breaker close operation

B5 DC Traction circuit breaker operation: Trip

Local trip operation

Figure 13 illustrates the desired control sequence for localling tripping the DC Traction circuit breaker. This diagram is indicative only and outlines the main control sequence requirements. The local trip operation shall only be possible if all of the following conditions are met:

- The umbilical cord is connected and the control voltage is available; and
- The control panel is in LOCAL mode.

If any of these conditions are not met and a LOCAL TRIP pushbutton is operated, the trip command shall be ignored. Otherwise, a shunt trip operation is initiated.

Once the operation has completed (or failed), the DC Traction circuit breaker status shall be updated locally.

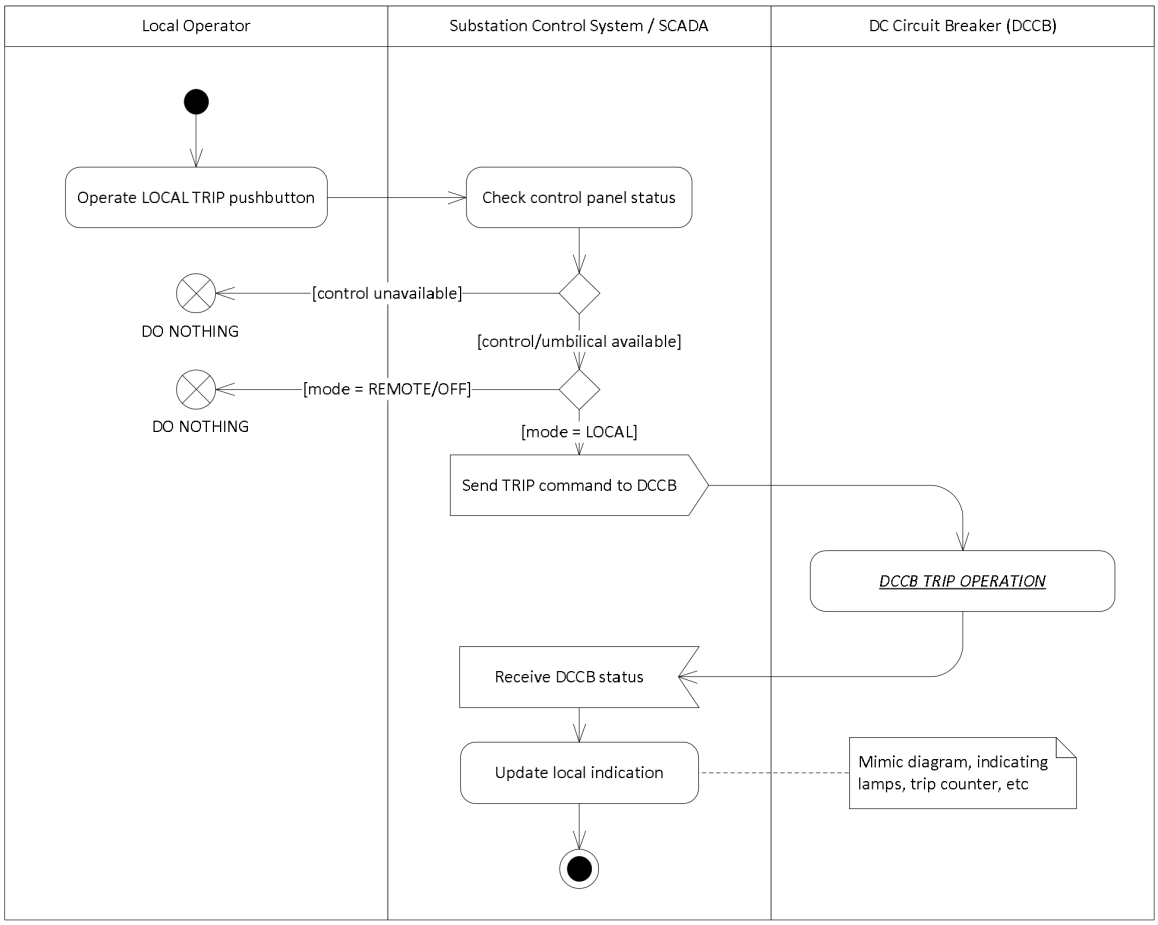

Figure 13: DC Traction circuit breaker local trip operation

Remote trip operation

Figure 14 illustrates the desired control sequence for remotely tripping the DC Traction circuit breaker operation. This diagram is indicative only and outlines the main control sequence requirements. The remote trip operation shall only be possible if all of the following conditions are met:

- The umbilical cord is connected and the control voltage is available;
- The control panel is in REMOTE mode; and
- The circuit breaker truck is in the IN SERVICE or TEST position.

If any of these conditions are not met and a REMOTE TRIP command is issued, the control room operator shall be notified (via SCADA) that the command is invalid. Otherwise, a shunt trip operation is initiated.

Once the operation has completed (or failed), the DC Traction circuit breaker status shall be updated locally and returned to the control room via SCADA.

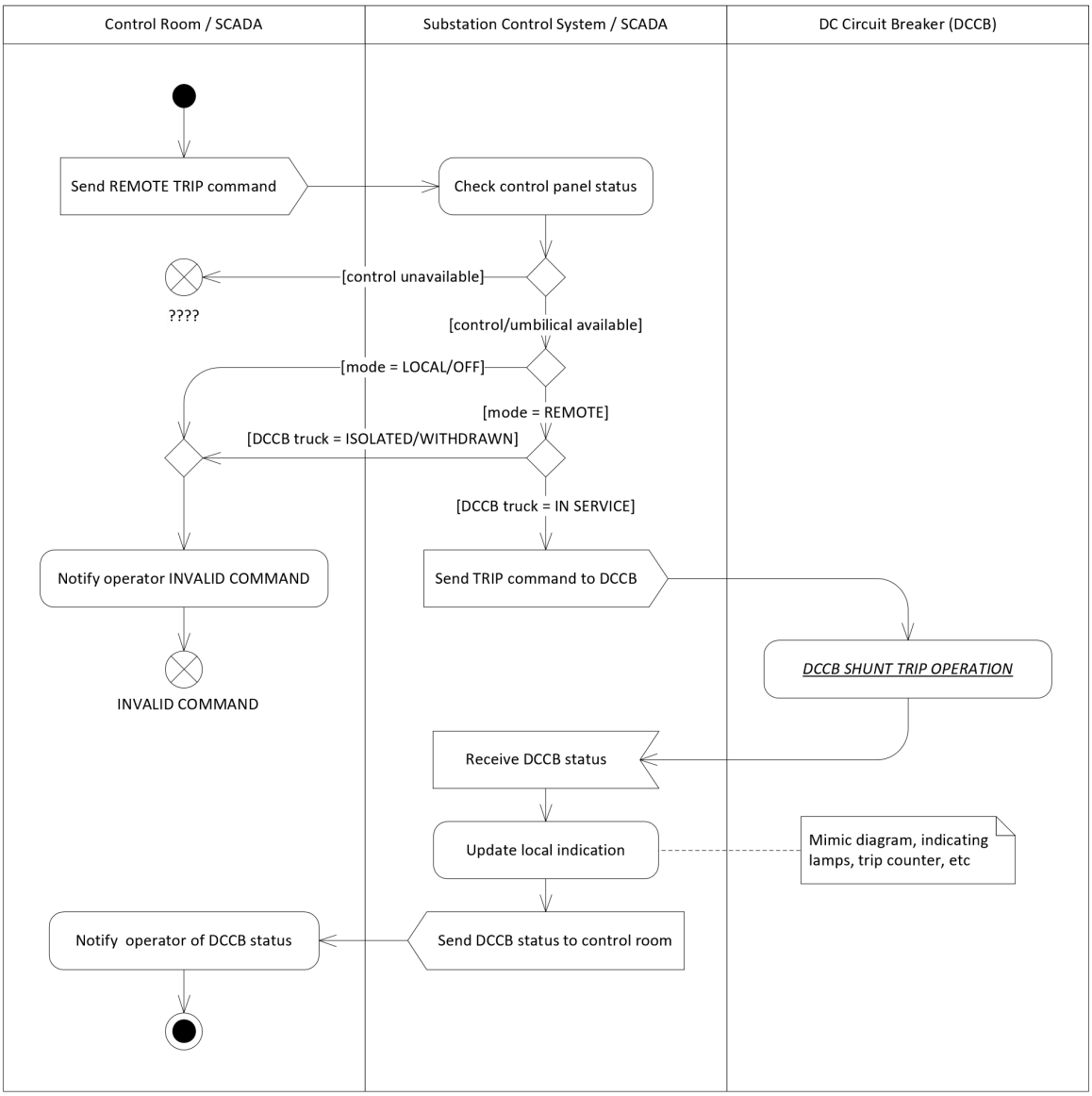

Figure 14: DC Traction circuit breaker remote trip operation

Shunt trip operation

Figure 15 illustrates the desired control sequence for an electrical shunt trip of the DC Traction circuit breaker. This diagram is indicative only and outlines the main control sequence requirements. The circuit breaker shall ignore the shunt trip command if:

- A trip operation is already in progress (anti-pumping); and
- The circuit breaker is already OPEN.

Once the trip has been initiated, if the circuit breaker trips successfully, the status of the contacts is returned to the substation control system (and SCADA). If the circuit breaker failed to open, then additional protective devices may be triggered (if installed) and the control system shall be notified of the circuit breaker failure.

A circuit breaker trip command shall interrupt any other command (e.g. line test or close operation).

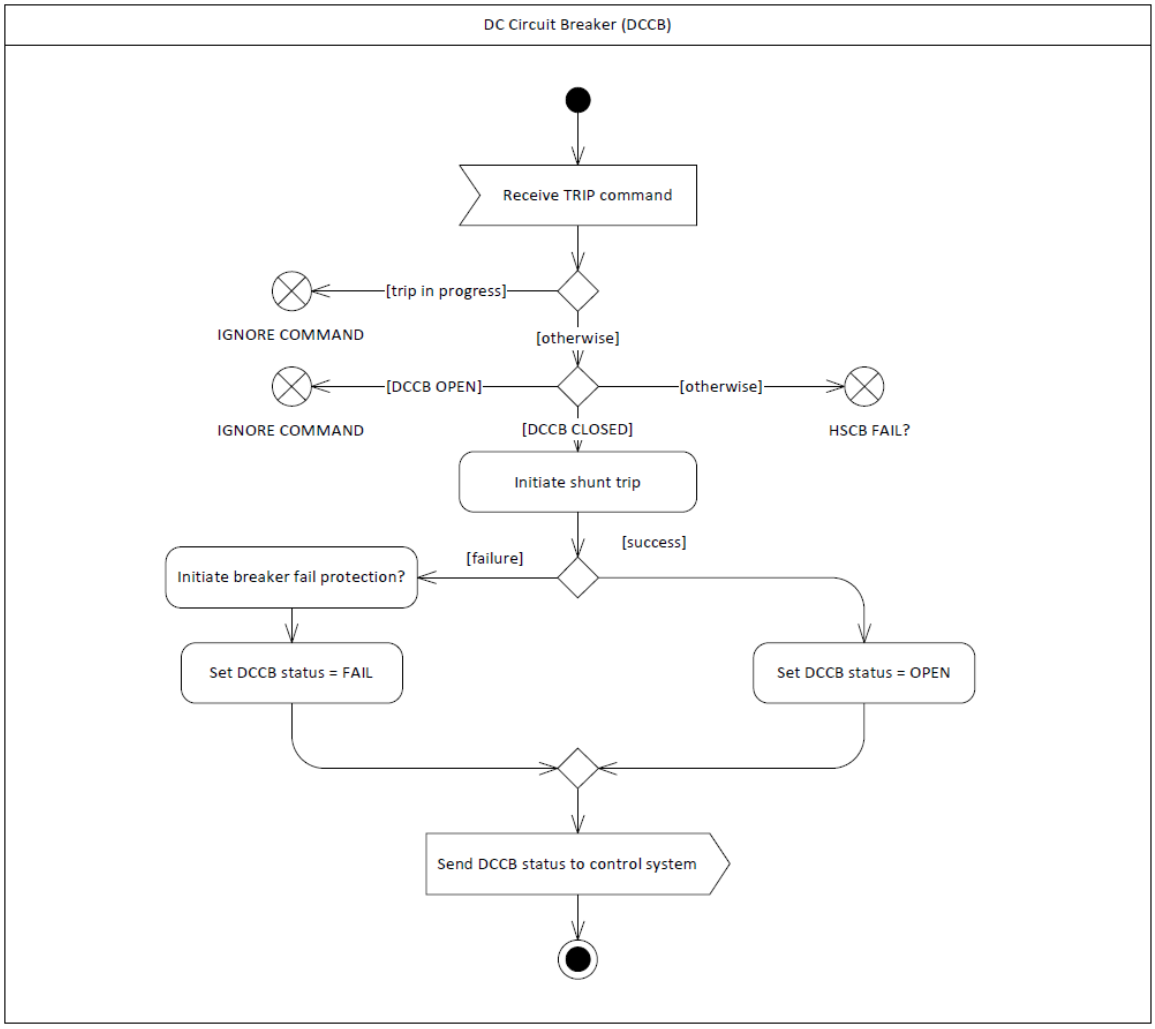

Figure 15: DC Traction circuit breaker shunt trip operation

B6 Fault reset

Local fault reset operation

When the local fault reset pushbutton is pressed and the control voltage is available, all non-persistent and non-critical fault conditions (e.g. line test failure) for the panel shall be reset. However, persistent or critical fault conditions (e.g. frame leakage) shall not be reset by this pushbutton.

Operation of the local fault reset pushbutton shall not trigger the operation of any main equipment in the panel.

Remote fault reset operation

Figure 16 illustrates the desired control sequence for remote fault reset operation of the DC Traction circuit breaker.

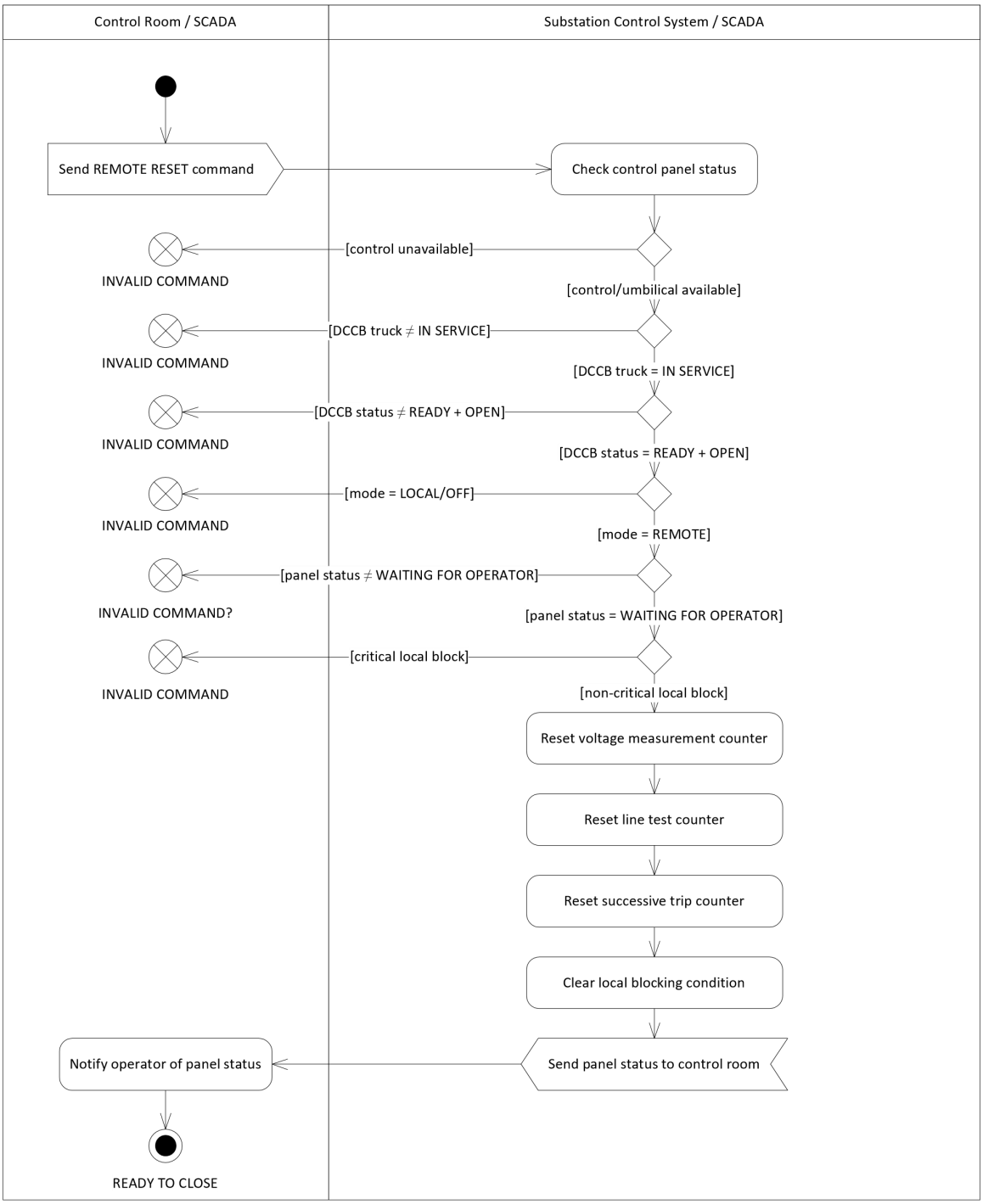

Figure 16: DC Traction circuit breaker remote fault reset operation

B7 Override pushbutton operation

Undervoltage override pushbutton operation

Whenever the undervoltage override pushbutton is operated, it shall override the undervoltage protection for the panel. The pushbutton shall only be operable if the following conditions are met:

- The umbilical cord is connected and the control voltage is available; and
- The panel is in LOCAL mode.

If the above conditions are not satisfied or the pushbutton is released, the undervoltage protection shall be re-enabled.

NOTE: This pushbutton is intended to be used for maintenance testing purposes (i.e. to allow the circuit breaker to be closed while it is withdrawn or isolated). In these situations, the normal closing sequence would fail because of the undervoltage protection. The pushbutton is not intended to be used to override the undervoltage protection when the circuit breaker is racked in.

Line test override pushbutton operation

Whenever the line test override pushbutton is operated, it shall override the line test control sequence for the panel. The pushbutton shall only be operable if the following conditions are met:

- The umbilical cord is connected and the control voltage is available; and
- The panel is in LOCAL mode.

If the above conditions are not satisfied or the pushbutton is released, the line test control sequence shall be re-enabled.

NOTE: This pushbutton is intended to be used for maintenance testing purposes (i.e. to allow the circuit breaker to be closed while it is withdrawn or isolated). In these situations, the normal closing sequence would fail because of the line test control sequence. The pushbutton is not intended to be used to override the line test control sequence when the circuit breaker is racked in.

NOTE: DC Traction rectifier circuit breakers do not have auto-reclose and line test functionality.

Lamp test pushbutton operation

Whenever the lamp test pushbutton is depressed and the control voltage is available, all lamps on the control panel shall be illuminated so that faulty lamps may be identified and replaced.

B8 Line test and auto-reclose control sequences

Line test control sequence

Figure 17 illustrates the desired control sequence for line test of the DC Traction feeder circuit breaker. This diagram is indicative only and outlines the main control sequence requirements.

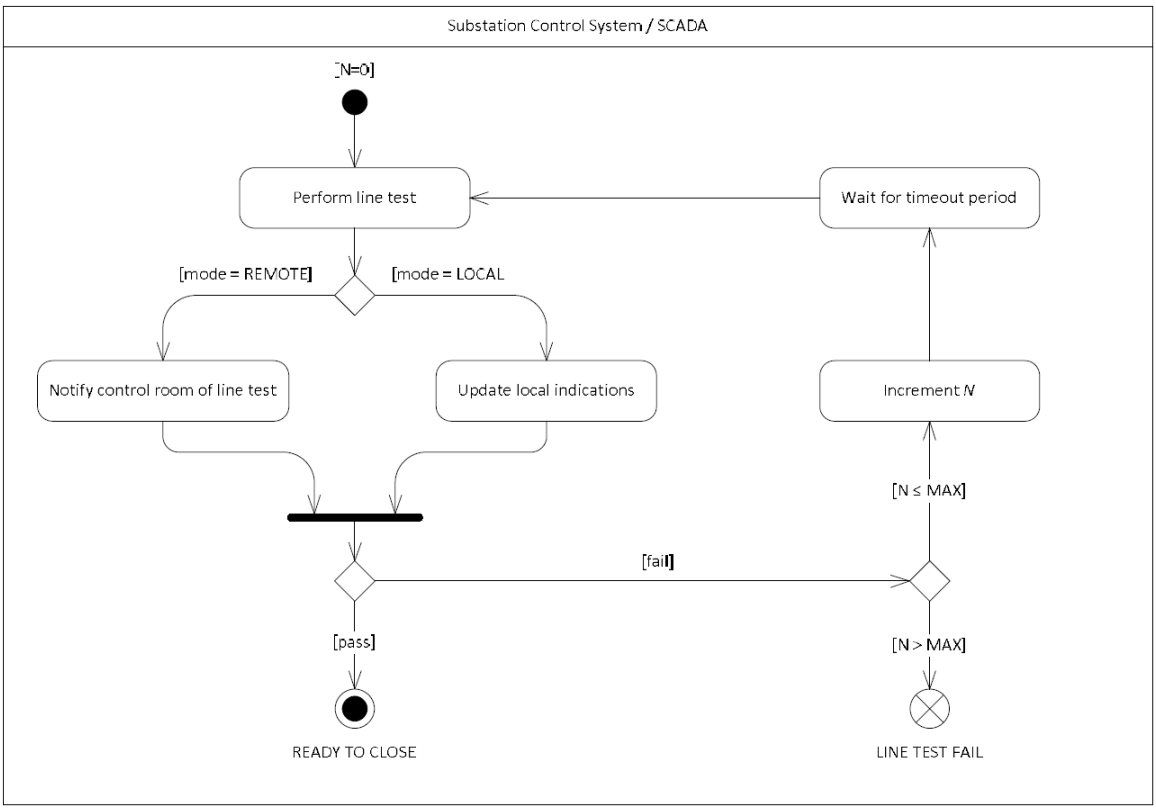

Figure 17: Line test control sequence

Line voltage measurement control sequence

Figure 18 illustrates the desired control sequence for line voltage measurement of the DC Traction feeder circuit breaker. This diagram is indicative only and outlines the main control sequence requirements.

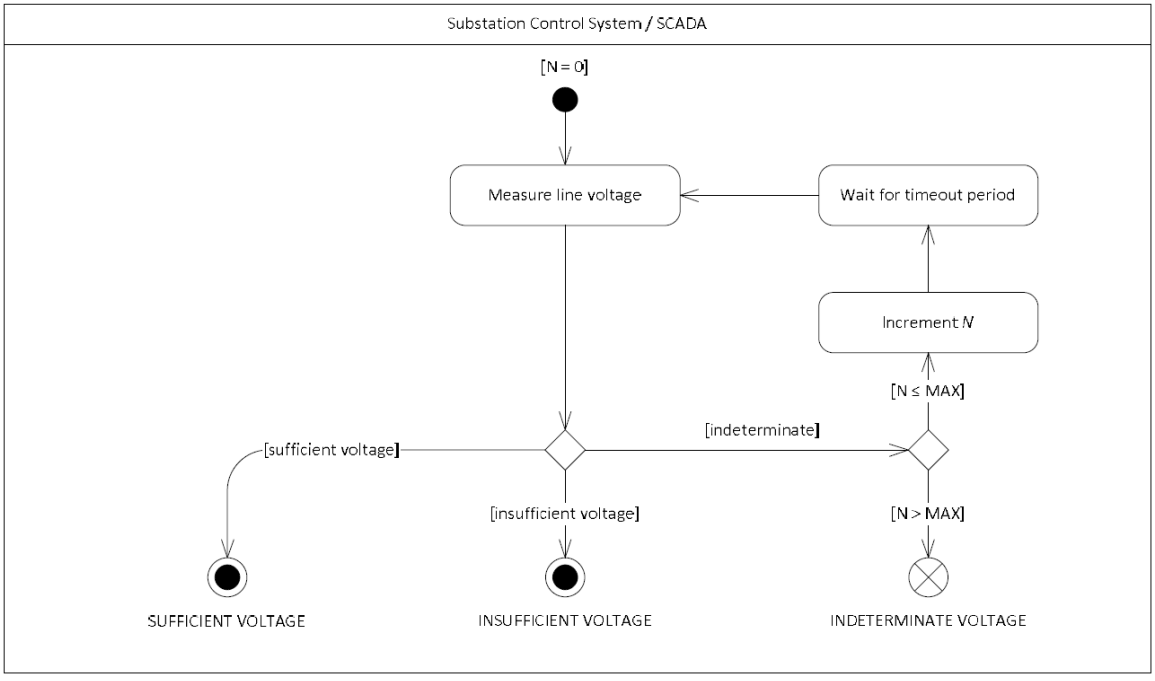

Figure 18: Line voltage measurement control sequence

Auto-reclose control sequence

Figure 19 illustrates the desired control sequence for auto-reclose of the DC Traction feeder circuit breaker. This diagram is indicative only and outlines the main control sequence requirements.

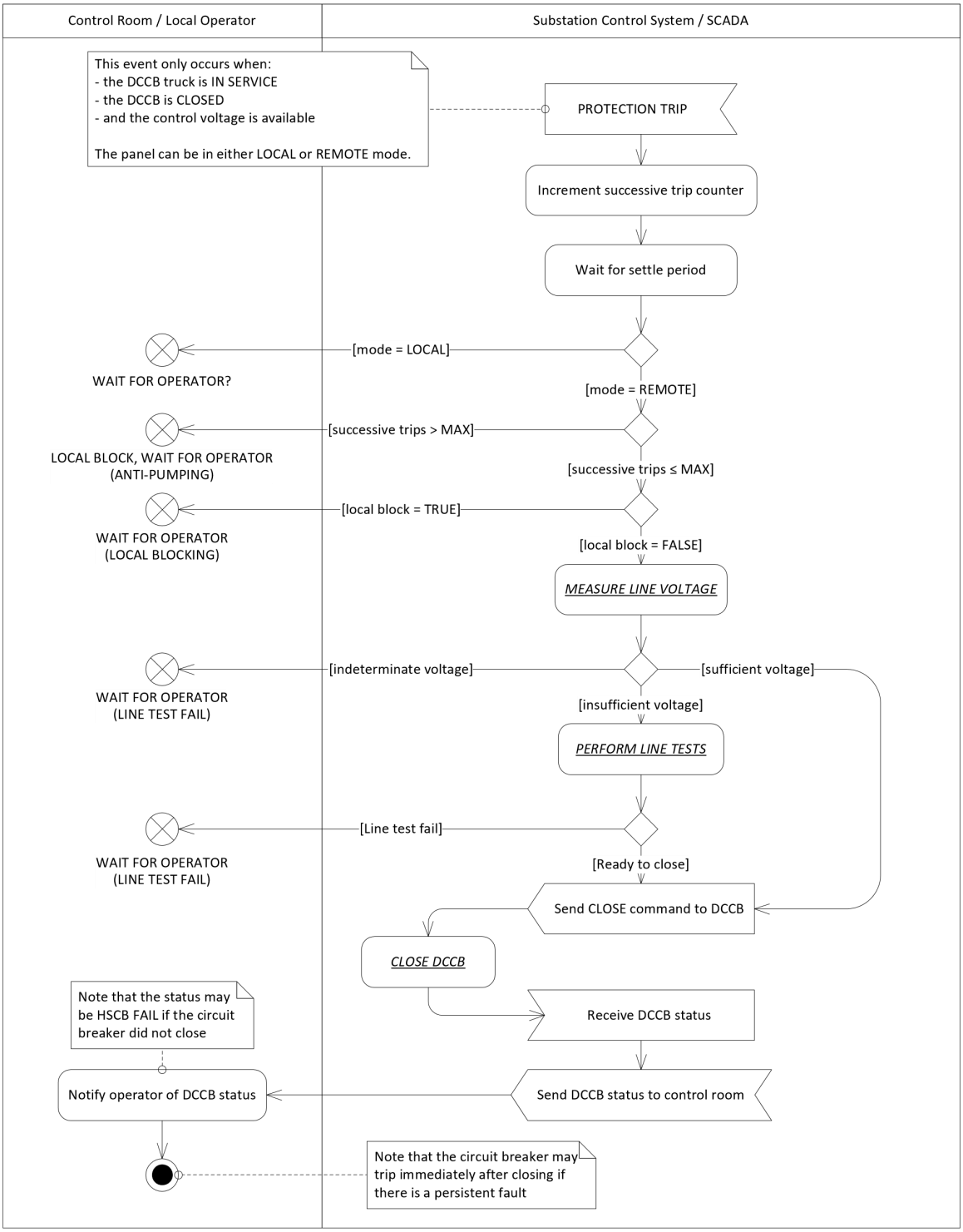

Figure 19: Auto-reclose control sequence

B9 Transfer and short-circuiting switch operation

Transfer switch operation

If a transfer bus is included in the *Scope of Works*, the arrangement will typically be as shown in Figure 20.

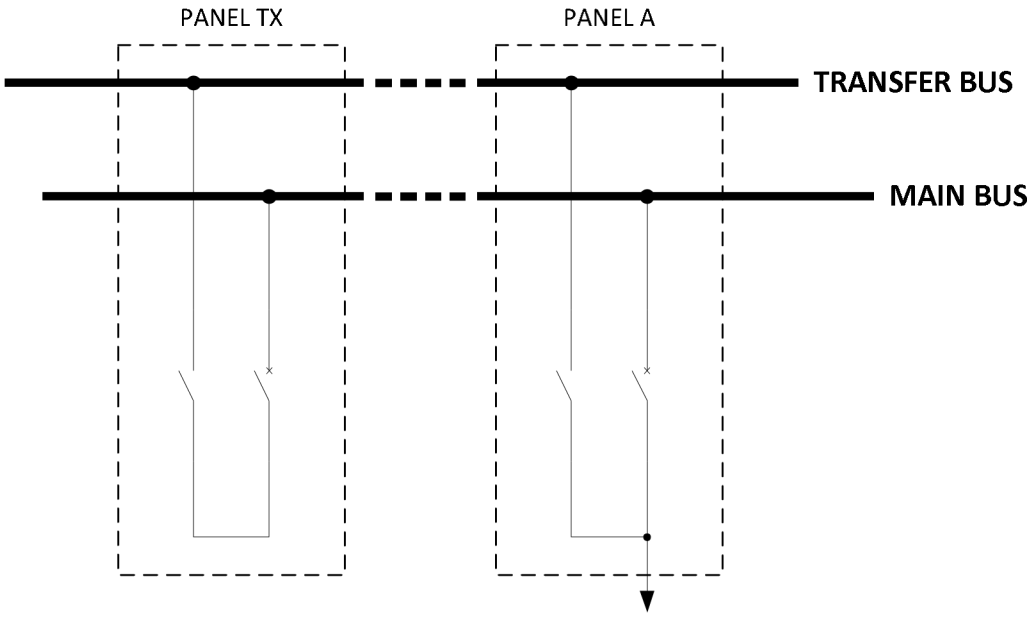

Figure 20: Transfer switch typical arrangement

In normal operation:

- DC Traction circuit breaker A is CLOSED;
- Transfer switch A is OPEN;
- DC Traction circuit breaker TX is OPEN; and
- Transfer switch Tx is OPEN.

The normal sequence of transferring control from panel A to panel TX is as follows:

1. Close transfer switch A;
2. Close transfer switch TX;
3. Close DC Traction circuit breaker TX; and
4. Trip DC Traction circuit breaker A.

The normal sequence of returning control from panel TX to panel A is as follows:

1. Close DC Traction circuit breaker A;
2. Trip DC Traction circuit breaker TX;
3. Open transfer switch TX; and
4. Open transfer switch A.

These sequences are intended to prevent operation of the transfer switches under load.

The transfer switches may be operated locally or remotely (or manually). The transfer switch pushbutton controls shall only operate a transfer switch if its respective panel is in LOCAL mode. Similarly, it shall not be possible to operate a transfer switch remotely unless the respective panel is in REMOTE mode. When the panel is in OFF mode, control voltage is unavailable or safety interlocking is in place, the transfer switch motor shall be inoperable.

It is desirable that the SCADA / substation control system should prevent more than two transfer switches being closed at any one time (i.e. the transfer panel should only be used to supply the load of a single DC circuit breaker, not multiple DC circuit breakers).

Short-circuiting switch operation

The short-circuiting switches shall be electrically and mechanically interlocked in conjunction with the respective main DC Traction circuit breaker and the associated transfer switch (where applicable) to prevent operation of the short-circuiting switch when the DC Traction circuit breaker or transfer switch is closed and to prevent closing of the circuit breaker or transfer switch when the short-circuiting switch is closed.

The short-circuiting switch shall be interlocked with the voltage sensing device designed to measure the voltage on the outgoing feeder cable(s).