THE CITY OF EDMONTON
DESIGN-BUILD AGREEMENT
CAPITAL LINE SOUTH LRT EXTENSION PHASE 1

Schedule 5 – D&C Performance Requirements

Part 6: Systems

[NTD: Schedule 5 D & C Performance Requirements – all parts – will be amended July 30 2024 to reflect requirements associated with Appendix A - Affordability Opportunities Amendment Term Sheet]

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PART 6: SYSTEMS

SECTION 6-1 – DESCRIPTION OF INFRASTRUCTURE

6-1.1 SUSTAINABLE URBAN INTEGRATION

A. Part 2 [*Sustainable Urban Integration and Landscape Architecture*] of this Schedule provides the overarching requirements for Sustainable Urban Integration (SUI). SUI key values, goals and objectives outlined in Section 2-1 [*General Sustainable Urban Integration Requirements*] of this Schedule must be met by the Design-Builder. Additional component specific SUI requirements have been incorporated in this Part.

B. SUI for Support Services Structures.

1. Buildings, movement systems, landscaped spaces, equipment enclosures and other supporting elements must be integrated by the Design-Builder with their urban context in fully coordinated ensembles.
2. Wayside enclosures, cubicles, UC/TPSS, and signal bungalows must be located in a manner that reduces visual clutter and maintains sight lines as required for Train Operators and LRT corridor users.
3. Wayside enclosures, cubicles, UC/TPSS, and signal bungalows are within designated Character Zones. These zones dictate the landscape treatment required within the zone. Refer to Section 2-9.6 [*Character Zones and Specialty Areas*] of this Schedule for requirements.
4. UC and TPSSs must meet the requirements provided in Section 2-9.6.7.2 [*Specialty Area 2: Utility Complexes/TPSS Landscape Requirements*] of this Schedule.
5. Wayside enclosures should be wrapped. Artwork on wraps, reflecting the Character Zone and specific location of each wayside enclosure, must be submitted by the Design-Builder for review.

6-1.2 DUCT BANKS

6-1.2.1 Infrastructure Description

A. The Systems Duct Bank provides a group of conduits to protect and consolidate cabling to and from different LRT systems.

B. The duct bank systems must be buried and encased in concrete.

C. The duct bank system is comprised of polyvinyl chloride, DB2 or HDPE conduits that are bundled together.

D. The Design-Builder must intercept three 103 mm underground conduits located west of the existing Heritage Valley Transit Centre building and extend them to the communication room in the Heritage Valley North UC.

E. The Design-Builder must Design and Construct 24-strand fibre optic cables inside the intercepted conduits to connect from the existing transit centre to the UC.

6-1.2.2 Reference Standards

A. The systems above are described in the HFDG Section 6.3 - “Duct Banks and Raceways and Section 11.11 – “Duct Banks and Raceways”.

B. The Design-Builder must integrate the new Systems Duct Bank with the Capital Line LRT Systems Duct Bank in accordance with Section 1-1.4 – [*Integration with Capital Line LRT*] of this Schedule.

6-1.2.3 Design Requirements

A. The Design-Builder must provide separate duct banks to accommodate cabling based on the fill factors of this Schedule for the following systems and facilities including:

   1. Systems duct banks:

      a. Signaling

      b. Communication

   2. PDS;

   3. LRT ROW Electrical;

   4. Utility power; and

   5. Spare (25% spare space per type in each conduit).

B. The Design-Builder must provide all components of underground reinforced concrete encased duct banks that are CSA and/or Underwriter's Laboratories of Canada approved listed and labeled.

C. The Design-Builder must join duct lengths together with a manufacturer accepted coupling to provide a sound and watertight joint.

D. The Design-Builder must provide the Systems Duct Bank extending continuously along the full length of the Capital Line LRT below grade, except where it is required to be concealed within structures.

E. The Design-Builder must provide underground secondary conduit connections sufficient to accommodate Project needs from the Systems Duct Bank to each UC, TPSS, Station, and Traffic Controllers located at signalized intersections.

F. The Design-Builder must provide sufficient conduit between the Llew Lawrence OMF building and the mainline to accommodate future Project requirements. This extra space should be between 25% to 33% and be easily accessible when the proposed future administration building is built.

G. The Design-Builder must provide appropriate fittings in the Systems Duct Bank Designed to accommodate all movement and prevent damage to the Systems Duct Bank, and the associated conduit, at any locations where rotation, horizontal displacement or vertical displacement may occur.

H. In accordance with Section 2-9 – [*Landscape Architecture*] of this Schedule, the Design-Builder must locate the Systems Duct Bank away from proposed or existing trees to prevent tree root intrusion of the Systems Duct Bank.

I. The Design-Builder must segregate electrical, communication and signaling cables in separate conduits along the full length of the Systems Duct Bank.

   1. The Design-Builder must prepare and submit system cabling separation guidelines to manage EMC crosstalk between cable groups and within each group of systems.

J. The Design-Builder must provide each conduit within the Systems Duct Bank to meet the following requirements:

1. Swept and mandrelled after installation to ensure a clean and non-obstructed installation. No cable may be installed prior to successful completion of these inspections.

2. Include bushings at all open conduit ends to protect cables.

3. Installed such that water must not accumulate in any section of the conduit.

4. Use polyvinyl chloride, DB2 or HDPE based conduit.

5. Include identification that follow existing City conventions.

K. The duct bank must meet the following requirements:

1. Minimum clearance from cable vault/pullbox with signal case edge to track center: 2.75 m.

2. Maximum cable vault/pullbox elevation: 100 mm below TOR.

3. Minimum cable vault/pullbox elevation: 100 mm above grade / top of ballast.

4. Minimum duct bank cover: 375 mm.

5. Minimum duct bank spacing: 300 mm.

L. Large radius sweeps must be used for any bends. Allow 20x the cable diameter for communication kits/cables. Use a cable vault/pullbox for every change of direction. No more than 180 degrees of curvature should be allowed between two cable vaults/pullboxes.

M. The Design-Builder must provide an appropriate grounding system for manholes.

N. The Design-Builder must ensure that cable pulling tensions are justified by calculation notes.

O. The Design-Builder must provide access vaults for the Systems Duct Bank as listed below but not limited:

1. at each Station;

2. at each end of the following Transportation Structures;

   a. the 23 Avenue NW underpass

   b. the Blackmud Creek LRT bridge

   c. the AHD LRT bridge

3. at each Utility Complex and TPSS;

4. at each intersection; and

5. adjacent to Llew Lawrence OMF building wall.

P. The Design-Builder must provide access vaults for the Systems Duct Bank with the following attributes:

1. Made of precast reinforced waterproof concrete and meeting the requirements of the code for reinforced concrete ACI, including all referenced standards and specifications AASHTO.

2. Able to withstand all loading from external factors in each installed location, withstanding the load requirements of the H-20 wheel.

3. Installed with protective collars for conduits entering and exiting access vaults with no exposed sharp or metallic parts that might damage the cables.

4. Provided with a clear legible identification label consistent with the City's latest labeling convention.

5. Placed within the LRT ROW or immediately adjacent to a UC/TPSS.

6. With sufficient 103 mm knockouts on each wall for incoming conduits, with a minimum of 12 103 mm knockouts on two walls.

7. With lockable covers suitable for operation in all environmental conditions.

8. With covers in accordance with AASHTO M306, and capable of withstanding the load requirements of the H20 wheel.

9. Free of sharp edges and provided with a center hatch which does not conflict with ladder rungs.

10. With racking on all four inside walls for cable dressing and suspension.

11. With a sloped floor and provided with a gravity drainage system to prevent accumulation of standing water.

12. With space and mountings for outdoor-rated fibre splice enclosures and cable slack.

Q. The Design-Builder must provide pull boxes, where required on local conduit runs, with the following attributes:

1. Able to withstand all loading from external factors in each installed location.

2. Installed with protective collars for conduits entering and exiting pull boxes with no exposed sharp or metallic parts that might damage the cables.

3. With a clear, legible identification label consistent with the City's latest labeling conventions.

4. Including covers lockable by concealed padlock.

5. Including covers in accordance with AASHTO M306, and capable of withstanding the load requirements of the H-20 wheel.

6-1.3 WAYSIDE EQUIPMENT

6-1.3.1 Infrastructure Description

A. Wayside equipment consists of double room signal bungalows and terminal equipment.

6-1.3.2 Design Requirements

6-1.3.2.1 General

A. The Design-Builder must provide wayside equipment enclosures (double room signal bungalows), where required to house wayside equipment, that are sized to house the equipment plus 20% spare physical space capacity.

B. The Design-Builder must provide each electrical load center with a dedicated surge suppressor in accordance with IEEE C62.41.1 Guide on the Surge Environment in Low-Voltage (1 kV and less) AC Power Circuits.

C. The Design-Builder must provide a separate battery ground fault detector for each isolated energy source, within a wayside equipment bungalow that contains energy sources for Vital equipment, and provide a scheduled ground fault detector testing regime within the maintenance manuals as described in Section 8 [*Training*] and 9 *[Operating and Maintenance Manuals*] of Schedule 4 [*Design and Construction Protocols*] that must ensure the ground fault detector functions properly:

1. The Design-Builder must ensure all battery ground fault condition alarms are reported to the Operations Control Centre (OCC).

2. The Design-Builder must provide equipment located within indoor locations (double room bungalows and UCs) in accordance with the HFDG.

6-1.3.2.2 Signal Bungalows

A. The Design-Builder must provide double room signal bungalows located in outdoor locations that:

1. Are Designed to operate properly in local weather conditions, including heavy winds, rain, hail, snow, ice, extreme outside air temperatures, and relative humidity up to 100%, per Section 1-3.1.3 [*Edmonton Climatic Requirements*] of this Schedule.

2. Are equipped with sun shields and convection vents so that maximum internal temperature rise above outdoor ambient air temperature does not exceed 25°C where enclosures and cabinets are subject to temperature extremes caused by exposure to direct sunlight in ambient temperatures of +40°C including heat from internal electrical losses. The bungalows must have monitorable air conditioning and heating systems connected to the communications monitoring system as defined in Section 2.8 of Appendix 6E [*Communications Design Preliminary Report*].

3. Are equipped to ensure a maximum internal relative humidity of 95% noncondensing.

4. Are equipped with heaters so that the internal temperature does not go below +15°C when the bungalows are subject to severe winter conditions and temperatures as low as -40°C.

5. Include Design and Construction measures to protect against deterioration due to salt, condensation, ice, snow, and temperature extremes, including control of fungus growth and metal corrosion.

6. Are lockable with an electronic padlock in compliance with the existing Approved Products List and include door opening monitoring for each of the doors.

B. The Design-Builder must Design and Construct double room signal bungalows based on the layout that can be found in Appendix 6D of this Schedule. The communication room is also described in Appendix 6E [*Communications Design Preliminary Report*].

SECTION 6-2 – TRACTION POWER

6-2.1 INTRODUCTION

A. The specifications contained in this section for the Traction Power System describe requirements that will inform the Design, supply, and Construction of the PDS and OCS for this Project.

B. The following Infrastructure elements are described in this section:

1. New TPSS, both stand-alone and within a UC
2. New PDS on mainline and at the Llew Lawrence OMF
3. New OCS providing sectionalized DC power to trains on the new alignment and at the Llew Lawrence OMF
4. Upgrades required at the existing Century Park substation for protection integration

C. Any deviation from the requirements of the HFDG must be identified and submitted to the City for review and approval.

6-2.1.1 System Description

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.1.1 – "System Description".

B. The TPS is used to distribute power to the LRV on Mainline Track and at the Llew Lawrence OMF.

C. The Project will extend the Capital Line LRT approximately 4.5 km from the Century Park Station and will include two new passenger Stations:

1. Twin Brooks Station
2. Heritage Valley North Station

D. The line is located in an urban area and crosses a high-voltage power transmission line. The high-voltage line is within the TUC, approximately 450 m south of the proposed Twin Brooks Station and 1 km north of the proposed Heritage Valley North Station.

E. Three new TPSS are proposed for the mainline of the Project:

1. Twin Brooks UC
2. Anthony Henday TPSS
3. Heritage Valley North UC

F. One new TPSS is proposed in the UC supporting the Llew Lawrence OMF.

G. Five DC distribution boards are proposed at the new Llew Lawrence OMF.

H. The Project Work for the OCS includes:

1. The Design, manufacture of materials and equipment, fabrication, supply of materials, installation, testing, commissioning, and incidentals necessary to complete the OCS construction and installation.

2. Limited deconstruction and reconstruction of OCS on the Capital Line LRT in accordance with Section 1-1.4 [*Integration with Capital Line LRT*] of this Schedule including interim training of the City.

3. Integration of the Project into the Capital Line LRT where the OCS on the Capital Line LRT currently terminates south of the Century Park Station.

4. The supply of all OCS special tools and spare parts as described in Schedule 4 [*Design and Construction Protocols*] to perform all preventative and corrective maintenance, and repairs.

6-2.1.1.2 Future LRT Extensions and System Renewal

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.1.1.1 – “Future LRT Extensions and System Renewal”.

B. The interface location to the Capital Line LRT OCS is located just south of Century Park Station.

C. The existing OCS must be extended to the next wire section to create a proper transition if different size contact wires are proposed.

D. The Design-Builder must ensure that new components at the interface with the existing OCS are compatible OCS material and component styles to the supplied materials installed on the Capital Line LRT.

6-2.1.2 Applicable Codes, Standards, Regulations, and Guidelines

A. The Design-Builder must ensure that the TPS and all associated Infrastructure comply with the following codes, standards and regulations, to the extent applicable:

1. American National Standards Institution

ANSI C37.09	Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI C37.14	Low-Voltage DC Power Circuit Breakers Used in Enclosures
ANSI C37.20.1	Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
ANSI C37.20.2	Metal-Clad and Station-Type Cubicle Switchgear
ANSI C37.20.3	Standard for Metal-Enclosed Interrupter Switchgear
ANSI C37.41	Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories
ANSI C37.90	Relays and Relay Systems Associated with Electric Power Apparatus
ANSI C39.1	Requirements for Electrical Analog Indicating Instruments
ANSI C57.13	Standard Requirements for Instrument Transformers
ANSI C62.11	Metal Oxide Surge Arresters for AC Power Circuits
ANSI C119.4	Connectors for Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Conductors
ANSI C37.34	Test Code for High-Voltage Air Switches

ANSI / NETA ATS	Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

2. Institute of Electrical and Electronics Engineers

IEEE C37.2	Electrical Power System Device Function Numbers and Contact Designations
IEEE 80	Guide for Safety
IEEE 142	Recommended Practice for Grounding of Industrial and Commercial Power Systems
IEEE 519	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE 1653.1	Traction Power Rectifier Transformer for Substation Applications up to 1.5 kVDC Nominal Output
IEEE 1653.2	Uncontrolled Traction Power Rectifiers for Substation Applications up to 1.5 kVDC Nominal Output
IEEE 1653.3	Guide for Rail Transit Traction Power Systems Modeling
IEEE 1653.4	DC Traction Power System Field Testing and Acceptance Criteria for System Applications up to 1.5 kVDC Nominal
IEEE 1653.6	Recommended Practice for Grounding of DC Equipment enclosures in Traction Power Distribution Facilities
IEEE C57.12.01	Standard General Requirements for Dry-Type Distribution and Power Transformers, Including Those with Solid-Cast and/or Resin Encapsulated Windings
IEEE C37.20.2	Standard for Metal-Clad Switchgear
IEEE C57.12.91	Test Code for Dry-Type Distribution and Power Transformers
IEEE C57.12.519	General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.18.10	Standard Practices and Requirements for Semiconductor Power Rectifier Transformers
IEEE P1653.2	Standard for Traction Power Rectifier Transformers for Substation Applications up to 1.5 kV DC Nominal Input
IEEE C37.04	Standard Rating Structure for AC High-Voltage Circuit Breakers
IEEE C37.06	AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis-Preferred Ratings and Related Required Capabilities
IEEE C37.20.1B	Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear Amendment 2: Additional Requirements for Control and Auxiliary Power Wiring in DC Traction Power Switchgear
IEEE C37.34	Test Code for High-Voltage Air Switches

IEEE 400	Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field
IEEE 404	Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV
IEEE 81	Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE 1106	Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Ni-Cad Batteries for Stationary Applications
IEEE 1189	Guide for Selection of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications
IEEE C37.20.3	Standard for Metal-Enclosed Interrupter Switchgear

3. National Electrical Manufacturers Association

NEMA PE-5	Constant Potential Type Electric Utility Battery Chargers

4. National Fire Protection Association

NFPA 70	National Electrical Code
NFPA 130 (for underpass sections)	Standard for Fixed Guideway Transit and Passenger Rail Systems

5. European Standard

EN 50122-1	Railway Applications – Fixed Installations – Electrical Safety, Earthing and the Return Circuit – Part 1: Protective Provisions Against Electric Shock
EN 50122-2	Railway Applications – Fixed Installations – Electrical Safety, Earthing and the Return Circuit – Part 2 Provisions against the effects of stray currents caused by DC traction systems

6. International Electrotechnical Commission

IEC 61000-5-2	Electromagnetic Compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling
IEC 62271-202	High-Voltage/Low-Voltage Pre-fabricated Substation

7. Others

   a. EPCOR Customer Connection Guide

   b. LEED Green Building Rating System

   c. AREMA Electrical Energy Utilization

   d. ASTM A780 Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dipped Galvanized Coatings

   e. Canadian Electrical Code Part I

   f. Canadian Electrical Code Part II

g. CAN/CSA C22.2 No 38: Thermoset-Insulated Wires and Cables

h. CAN/CSA 22.2 No 0.3: Electrical features of fuel-burning equipment

B. The OCS and all associated Infrastructure must comply with and must adhere to the following codes, standards and regulations, to the extent applicable:

1. Canadian Electrical Codes, CSA C22.1:21, C22.2 No. 0:20
2. CSA C22.3 No. 1:20 Overhead Systems
3. AISC
4. ASTM
5. National Electrical Safety Code
6. IEEE
7. Underwriters Laboratories
8. IEC
9. NEMA
10. AWS – D1.1 Structural Welding Code

C. All relevant structural codes in accordance with Section 4-2 – [*Reference Documents*] of this Schedule.

D. All Codes mentioned in the HFDG Section 6.2.1 – "Applicable Codes, Standards and Regulations".

6-2.1.3 TPS Elements

6-2.1.3.1 TPSS

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.1.3.2 – "TPSS".

B. TPSS is composed of the following main systems and equipment:

1. Medium Voltage Alternating Current Switchgear
2. TP Transformer
3. TP Rectifier
4. Interphase Transformer
5. DC Switchgear
6. Feeder and tie switches
7. 125 V_{DC} Battery Charger and Bank
8. 120/208 V_{AC} Distribution Panel
9. Primary and Station service utilities metering panels

10. Emergency trip buttons

11. Control Command Cabinet PLC and RTU

12. Negative Ground Switch

13. Grounding and bonding

14. Coordination of the electrical utilities

15. Disconnect Switches

6-2.1.3.2 OCS

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.1.3.3 – "OCS".

B. Material

   1. The Design-Builder must provide cables, conductors, and wires with a composition, quality and purity, such that the finished product has the properties and characteristics described in this Schedule and the referenced standards.

      a. All cables, conductors, wires, and ropes of the same Design must be uniform size and shape.

C. Performance

   1. The physical, mechanical, and electrical properties of the cables, conductors, wires, and ropes must conform to the requirements of this Schedule and the pertinent provisions of all standards referenced in Section 6-2.3 [*Overhead Traction Power System*] of this Schedule.

   2. All cables, conductors, wires, and ropes must have a minimum Service Life as defined in HFDG Section 1.3.5 – "Service Life and Design Life".

D. Fittings and Hardware

   1. OCS fittings and hardware material composition must be the same as the Capital Line LRT.

E. Support and Registration Assemblies

   1. Materials

      a. The OCS support and registration assemblies' material composition must be equivalent to the Capital Line LRT.

      b. All components used in the support and registration assemblies must be of sufficient strength and durability to withstand the design loads, with a minimum factor of safety of 2.5 relative to operating conditions.

      c. The assembly material must be strong, lightweight, and reliable to meet design life requirements as defined in HFDG Section 1.3.5 – "Service Life and Design Life".

      d. The cantilever and support assemblies must be of a proven tested design, that have been used on other overhead electrified rail systems and have demonstrated an acceptable performance history and in-service life in a climate similar to Edmonton.

      e. Cantilever support assemblies must meet the SUI requirements in Part 2 [*Sustainable Urban Integration and Landscape Architecture*] of this Schedule.

2. Installation Requirements

   a. The Design-Builder must locate cotter pins and nuts on each cantilever on the same side of the structure for uniformity, and ease of maintenance and inspection by facing maintenance personnel approaching in the direction of normal train travel.

   b. The Design-Builder must orient assemblies fitted with pins, cotters, bolts, and nuts where possible to lock these components together by gravity if the pins or nuts should become detached under service conditions.

   c. The Design-Builder must grease components employing a hinge or swivel with an Accepted grease before assembly of the rubbing surfaces, as recommended by the OCS manufacturer/supplier.

6-2.1.4 Load Flow Study

A. The Design-Builder must perform and submit the results of a Load Flow Study as detailed in HFDG Sections 6.1.4 – “Load Flow Study” and 6.1.5 – “TPS Loads and Parameters”.

B. The Load Flow Study must validate the TPSS locations, track and negative feeder cable numbers, the ratings of the TPSS, the rating of the contact wire / messenger wire (if applicable) and parallel messenger wire (if applicable). The TP requirements for Llew Lawrence OMF Site must be considered as part of this study.

C. The Design-Builder must develop and assess the TPS Design using computer simulation software intended for the purposes of TPS modeling as specified in IEEE 1653.3.

   1. The load flow simulation tool utilized must be commercially available and have been previously independently validated on a 660 V_{DC} nominal TPS.

D. The Design-Builder must base the Load Flow Study on the worst-case operating scenario while:

   1. following LRV parameters in both static and dynamic cases for mainline operation and Llew Lawrence OMF operation;

   2. ensuring that the TPS Design can sustain LRV operations based on an AW3 loaded five-car consist; and

   3. addressing two scenarios: full and half acceleration design criteria, in accordance with HFDG Section 6.1.5.1 – “Full Acceleration Design Criteria”" and Section 6.1.5.2 – “Half Acceleration Design Criteria (Reduced Operation)”.

      a. Submit load flow studies for full acceleration scenarios at each Station and half acceleration scenarios for each TPSS out of service including the existing Century Park TPSS.

E. Loading parameters of the LRV to be used for the study must be confirmed during Design.

6-2.1.5 TPS Loads and Parameters

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.1.5 – “TPS Loads and Parameters”.

B. TPSS ratings must comply with the minimum requirements in table below.

Table 6-2.1.5-1 Mainline TPSS Minimum Ratings

Number	Traction Power Substations	Ratings (kW)
1	Twin Brooks Station	1 x 2000
2	Anthony Henday	1 x 2000
3	Heritage Valley North Station	1 x 2000
4	Llew Lawrence OMF	2 x 2000

1. Final TPSS ratings must be confirmed by the Load Flow Study.

6-2.2 TPSS

6-2.2.1 General Design Principles

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.1 – "General Design Principles".

B. Coordination with utility for substation connections:

1. The Design-Builder must make arrangements with and obtain primary power connection to each TPSS from EDTI following the requirements of HFDG Section 6.2.3.4 – "Medium Voltage Utility Service".

2. The Design-Builder must confirm TPSS equipment compatibility and interoperability in compliance with the Customer Connection Guide.

C. Integration with Capital Line LRT TPSS:

1. The Design-Builder must provide system integration between the Capital Line LRT and the Project for control and protection schemes.

2. If an existing TPSS must be updated or upgraded to connect properly with the Project (i.e., the existing Century Park TPSS), general design principles must be respected.

D. All TPSS drawing submissions must follow the requirements and packages indicated in Schedule 4 [*Design and Construction Protocols*].

6-2.2.2 Studies and Calculations

A. Detailed Design must include studies listed in this section to establish the overall Design Data, as per HFDG Section 6.2.2 – "Studies and Calculations". The Design-Builder must submit the results/reports of these studies.

6-2.2.2.1 Protection and Coordination Study

A. The Design-Builder must coordinate the Design of the TPS protection scheme, according to HFDG Section 6.2.2.2 – "Protection and Coordination Study", with EDTI to achieve margins between all levels of protection systems sufficient to ensure that all schemes and time current characteristics allow for full use of the rated capacity of all equipment.

B. The Design-Builder must ensure ETS TPS protection scheme is followed as provided in Appendix 6C. This philosophy must be applied across all TPSS for consistency with the existing high floor LRT system.

6-2.2.2.2 Arc Flash and Incident Energy Study

A. The Design-Builder must provide an arc flash and incident energy study, as per HFDG Section 6.2.3 – "Arc Flash and Incident Energy Study", to mitigate any potential arc flash hazards.

6-2.2.2.3 Lightning/Surge Analysis

A. The Design-Builder must provide an insulation coordination study, as per HFDG Section 6.2.2.5 – "Lightning/Surge Analysis", to confirm the basic insulation level of the TPSS and OCS equipment. The study must also confirm the rating and placement of lightning and surge devices along the TPS from the MV supply through to the OCS.

6-2.2.3 TPSS Facilities

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.3 – "TPSS Facilities".

B. TPSS Environment:

   1. TPSS enclosures must conform to HFDG Section 8.4.13 – "Equipment Enclosures" and the following requirements.

   2. The Design-Builder must provide TPSS material and equipment suitable for its intended environment:

      a. for wet locations, provide NEMA 4X corrosion resistant stainless steel enclosures;

      b. for wet locations, provide corrosion resistant fittings or supports, hot-dip galvanized or as otherwise specified; and

      c. for exposed dry locations, corrosion resistant painted finishes may be used for equipment and enclosures, as acceptable to the City acting reasonably.

   3. Dissimilar metals are only permitted at permanent connections provided that the following conditions are met:

      a. connections are provided with a suitable electrochemical isolation; and

      b. isolation treatments are permanent with no requirement for maintenance or replacement for the life of the equipment or installation.

6-2.2.3.1 Building Design

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.3.2 – "Building Design".

B. All TPSSs, whether pre-fabricated or built-in-place, must:

   1. prevent unauthorized access through a controlled door access system;

   2. be constructed to ensure that the public and the City personnel are protected from exposure to hazards including voltage, arc flashes, toxic/harmful liquids or gases, and explosion risks;

   3. be Designed to allow any equipment in the TPSS to be safely and reliably maintained and where required, to be removed, replaced, reinstalled, commissioned and returned to full operation; and

   4. be equipped with a HVAC system as per the requirements stated in the HFDG for TPSS and maintaining positive pressure to reduce dust ingress. Reference to HFDG Section 6.2.5.3 –

"TPSS/UC Building Systems", Section 10.10.1.3 – "Mechanical Requirements", and Chapter 12 – "Mechanical".

C. Pre-fabricated TPSS buildings must comply with IEC 62271-202 and Section 2-1 [*General Sustainable Urban Integration Requirements*] of this Schedule.

D. Each pre-fabricated or built-in-place TPSS must use TP equipment of consistent make, model and ratings to all other Project pre-fabricated or built-in-place TPSS.

E. Each TPSS housed within a UC must follow the requirements of Section 5-3.9 [*Stand-Alone Utility Complexes and TPSS*] of this Schedule.

6-2.2.3.2 Grounding

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.3.8 – "Grounding".

B. The Design-Builder must prepare and submit each TPSS site's soil resistivity readings used for ground grid Designs.

C. The Design-Builder must prepare and submit the Design Data and associated calculations/simulations.

   1. The TPSS ground grid Design must include step, touch, and ground potential rise analysis as per IEEE 80. The analysis must conform to the requirements of the HFDG Section 6.2.2.4 – "Step, Touch, and Ground Potential Rise Analysis".

D. The Design-Builder must provide the TPSS ground grid Design Data around the perimeter of TPSS building or UC in accordance with IEEE 80.

   1. Ground grid Design for the TPSS must be coordinated with the UC ground grid if applicable.

   2. Ensure that TPSS ground grid resistance is 1 Ω or less.

E. The Design-Builder must prepare and submit each site's final ground grid resistivity readings to support ground grid Designs.

F. The Design-Builder must redesign and reinstall any ground grids that do not meet Project requirements.

G. A grounding bus must be provided adjacent to the metering transformers. Transformer enclosures must be bonded to ground.

H. DC switchgear and rectifier frame should be insulated from ground.

I. Feeder and tie switch frame should be insulated from ground.

J. The Design-Builder must ensure appropriate grounding is provided for manholes.

6-2.2.4 TPSS Equipment

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4 – "TPSS Equipment".

B. Materials and Equipment Requirements

   1. TPSS materials and equipment must be new and suitable for the use intended and of the latest standard design by the manufacturer.

2. The Design-Builder must provide TPSS materials and equipment which are standard products of manufacturers regularly engaged in the production of such material and equipment.

3. Where two or more units of the same class of TPSS material or equipment are required, provide products of a single manufacturer.

4. The use of discontinued TPSS materials or products is not permitted.

5. Each type of TPSS material and equipment must be of the same manufacture and quality throughout each of the TPSS.

6. The Design-Builder must submit a final recommended TPSS spare parts list to the City for review and acceptance.

6-2.2.4.1 Medium Voltage AC Switchgear

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4.2 – "Medium Voltage AC Switchgear".

B. The Design-Builder must ensure that the AC switchgear is a front access, freestanding metal cubicle including withdrawable circuit breakers.

   1. The switchgear must be anchored to the floor. Anchor location and supply must be coordinated with the building Design.

C. The AC switchgear and circuit breakers must be manufactured in accordance with IEEE and CSA standards.

D. The AC switchgear rear bus compartment must be manufactured to IEEE C37.20.2 – Standard for Metal-Clad Switchgear.

E. The Design-Builder must ensure that the equipment is suitable for use in an indoor environment, including the requirements associated with ambient temperature.

F. The following doors and components must be secured by a padlock:

   1. Circuit breakers

   2. Potential Transformer drawers

   3. Incoming and outgoing cables

   4. Metering transformers

   5. Protection transformers

   6. Utility metering transformers (include provisions for sealing)

G. The Design-Builder must meet the following requirements:

   1. Safety grounding ball studs (Chance type C600-2102, or other as Accepted by the City, with cover #C406-0416) must be provided attached to the ground bus at the back of each cell for easy access and for making ground connection during switchgear maintenance and/or testing.

   2. Each compartment for circuit breaker, bus, instrument transformer, and outgoing cable must be isolated from each of the others by formed steel sheet metal barriers. Adjacent cubicles must be isolated from each other over the entire face including the bus opening to adjacent cubicles.

3. Openings and cable support must be provided in the cell floor for bottom entry control cables.

4. Coloured phase designations or numbered markings must be readily visible in each bus, CT, PT, cable termination and breaker compartment.

5. Control relays, timers, and auxiliary relays must be surface mounted within the instrument compartment of their associated circuit breaker.

6. All control and instrument wiring entering or leaving the switchgear assembly must be wired through the terminal blocks. This includes breaker control circuits, status, alarms, transducer outputs, relaying, interlocks, PT, and CT secondaries. All wiring must be point-to-point. Splicing or "T" connections will not be accepted. No more than two wires may be connected to any one terminal. All internal wires must be clearly and permanently identified at both ends.

7. No control wiring connecting devices in different cells or cubicles may be run directly. Instead, wiring from each device must be taken to the terminal block in that cell and the interconnection between the cells made by means of jumpers. Each wire must be suitably numbered or identified.

8. All CT secondary and control wiring within a 15 kV compartment must be protected by a grounded armored shield.

9. Each set of PTs must be housed in a separate compartment. The mechanism to isolate the PT cabinet must be a drawer with linear pull movement to withdraw. A tilt out mechanism is not acceptable. An automatic safety shutter must be provided to protect personnel from accidentally contacting the primary contacts when the drawer is opened.

10. On withdrawal of the PTs, provisions must be made to prevent arcing on the primary disconnect contacts by arranging the secondary disconnect contacts to break before the primary contacts part. An automatic safety shutter must be provided to protect personnel from accidentally contacting the primary contacts when the drawer is opened. Provisions must be made to prevent personnel from contacting the PT primary fuses until after the primary disconnect contacts have separated a safe distance and have been automatically and properly grounded. Means must be provided to permit changing the high and low-voltage fuses without necessitating time consuming disassembly.

11. All protective relays, indicating, and metering devices must be front panel mounted and must be supplied in flush or semi-flush mounting cases.

12. Complete testing and calibration of the relays in the plugged-in position must be possible without disturbing other associated circuits.

13. Provisions for relay testing must also be facilitated with front surface mounted ABB Flexitest Type FT-1 test blocks for each relay.

14. Automated transfer to the standby feeder must occur on a "break-before-make" scenario utilizing voltage sensing. EDTI requires that returning to the main feeder be performed manually.

15. Main and standby cells must include surge protection in accordance with HFDG Section 6.2.7 – "Protection Relay Descriptions".

16. AC switchgear must be specified with partial discharge and acoustic monitoring ports. The ports must be fully arc rated and not reduce the arc flash rating.

17. AC breakers must be specified with an under-voltage trip coil. The under-voltage coil will be used as a redundant trip coil and to provide loss of control circuit protection as well as trip coil monitor protection.

18. Circuit breakers and circuit breaker compartments must be constructed to ensure the interchangeability of identical circuit breakers and compartments. All compartments for circuit breakers must include a shutter in the barrier between the breaker and the bus connections, which will automatically close the opening to the stationary disconnects of the compartment when the circuit breaker has been withdrawn to the disconnected or test position. The shutter action must be Designed to be positive in its operation.

19. Each circuit breaker compartment must be provided with a truck-operated cell switch. The switch status must be monitored.

20. A method must be provided to prevent a breaker from being racked into the connected position when padlocked in the test or disconnect position.

21. Each switchgear cell must include the following:

    a. Local/remote switch.

    b. Line 1/line 2/manual switch on main incoming cell to control the auto-transfer scheme.

    c. Control switch for local tripping of circuit breaker.

    d. Red light (closed) and green light (open) indication. Red and green lights for breaker closed and open indication respectively must be provided for each breaker cell on the front hinged panel. It must be possible to replace bulbs without opening the door. Indicating lights must be full voltage, push to test, LED type.

    e. Relay isolation switches for PT inputs.

    f. Relay isolation and shorting switches for CT inputs.

    g. Relay isolation switches for all trips leaving the cell, and trips to lock out relays.

    h. Terminal blocks in each compartment of the breaker cell must be mounted to provide easy access to terminations and to enable the wire numbers to be read without difficulty.

    i. Terminal blocks must have an average of at least one spare terminal for and adjacent to every eight terminals used. In addition, a minimum of 10% spare terminals must be provided in each terminal block assembly. Terminals must be adjacent for conductors in the same cables. Terminal blocks must be Weidmuller SAK 6N or a City Accepted equivalent. Compression style terminal blocks will not be accepted.

    j. 86 lockout relays in appropriate cells.

    k. Trip coil circuit monitoring with status indication.

22. A method must be provided for maintenance purposes to operate each circuit breaker via the breaker's secondary contacts when the breaker is outside of its cell. One set of tools consisting of the following must be supplied with each AC switchgear:

    a. Transport dolly for lifting and handling the circuit breaker outside the housing.

    b. Levering crank for moving the circuit breaker between the test and connected positions (if applicable).

    c. Secondary contact extension cord.

    d. Manual spring changing lever (if applicable).

e. Slow close lever (if different than charging lever).

23. A test Station must be provided for AC breakers.

24. All inter-panel cables must include 10% spare wires.

H. The Design-Builder must submit layout, mechanical, control schematic, and wiring drawings.

I. The Design-Builder must submit logic drawings for all close, trip, lockouts, interlock schemes, and transfer trips.

6-2.2.4.2 DC Switchgear

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4.3 – "DC Switchgear".

B. The DC switchgear assemblies at each mainline TPSS must consist of four track feeder breakers and one rectifier breaker.

C. Include draw out, single-pole DC power circuit breakers, DC positive buses and bus connections, indicating lights, terminal blocks, protective and auxiliary relays, control circuitry, wiring, and all other devices necessary to make a complete and operable assembly on each switchgear assembly.

D. Ensure that the height of components allows for the required servicing, maintenance or adjustment of the relays and devices installed in or on the switchgear assembly. Such components, relays and devices must be accessible from the front of the lineup.

E. The switchgear must serve as the control and protective equipment for the distribution of DC power to the LRVs.

F. Ensure that switchgear assemblies are provided with appropriate ratings for the loads and environment.

G. DC switchgear and rectifier must be equipped with frame fault protection (grounded frame and hot structure for stand-alone units only) as per HFDG Section 6.2.7.10 – "DC Switchgear and Rectifier Frame Fault Protection".

H. The Design-Builder must meet the following requirements:

1. Supply insulated matting to provide a 2 m protection zone in front of the entire DC switchgear lineup. The matting must be able to withstand the DC breakers being racked out of the cells for maintenance. The matting must be rated for a minimum of 2000 V.

2. Each circuit breaker cell must be equipped with automatic shutters, such that after withdrawal of the circuit breaker from a connected position into a test or disconnected position, access to the positive DC bus is restricted by the automatic shutters.

3. All breaker cells must be suitable for acceptance of any circuit breaker of the same rating but must block the accidental use of other breakers of different ratings.

4. A separate analog voltmeter must be supplied for the line side of the DC main circuit breaker. Voltmeters must read positive to negative volts on a long scale with accuracy class 1.0%, and a range from 0 to 1000 V DC.

5. A separate analog ammeter must be supplied for the DC main and each feeder breaker cell. Ammeters must read DC amps on a long scale with accuracy class 1.0%, and a range from 0 to 6000 A for main cells.

6. A protection class, low impedance frame over-current relay must be provided in series with the single point connection from the ground bus in the DC switchgear to the Station ground grid. The connections must be capable of terminating two 350 MCM stranded copper conductors utilizing 2-hole NEMA compression connectors. All devices, where grounded, must be grounded utilizing stranded conductors.

7. Wiring:

   a. All internal cell cubicle and breaker wiring must be properly dressed and identified at both ends. The wire identification must be machine printed, permanent and in accordance with the schematic diagrams and wiring diagrams.

   b. No wire splicing is permitted. No more than two wires must be connected to any one terminal point. Wiring must be properly terminated to terminals capable of withstanding a pull-out force of at least 640 N. Automotive type slide-on connectors to relays and auxiliary control devices are not permitted. All cell-to-cell wiring must occur between terminal blocks, not device to device.

   c. All wiring must be neatly run in wiring trays with covers. Where wire bundles are subject to movement, suitable protective jacketing must be installed. The minimum clear distance provided between adjacent terminal strips must be 150 mm.

   d. All manufacturer supplied control and protection circuit wiring must not be less than #14 AWG stranded copper. Wiring for all shunt, direct bus connected or DC current transformer circuits must not be less than #12 AWG stranded copper. All conductors must have an allowable temperature rise of 90°C. All control, metering, and relay wiring must be stranded, and all stranded conductors must be either flexible (19 strands) or extra flexible (37 strands). Solid conductors are not permitted. All transducer output leads must not be less than #20 AWG with each pair of output leads individually shielded to prevent stray induction and interference. Shields must be terminated on terminal blocks, associated with each pair or triad. Care should be taken to ensure multiple ground paths are not introduced by cable shield connections. The Design-Builder must ensure that no external grounds are introduced into the DC switchgear through control and communication cables. All control wiring must be rated 600 V_{AC}, 90°C. Where high-voltage (i.e., rated 750 V_{DC}) connections are made to instruments and relays, the wiring must be 1000 V RW-90, coloured black.

   e. Insulated boots and covers must be removable to allow access to the termination but must be captive to avoid being misplaced.

   f. All control wiring must be bundled separately from the high-voltage DC wiring.

   g. Single or groups of devices in one cell having terminals connected to a common bus may take their supply from one point. These devices must be clearly shown on the drawings by the Design-Builder such that in the event of a ground in the control system, the fault can easily be traced. No control wiring connecting devices in different cells or cubicles must be run directly. Instead, wiring from each device must be taken to the terminal block in that cell and the interconnection between the cells must be made by means of jumpers. Each wire must be suitably numbered or identified.

   h. All similar cells must have identical wiring configurations. Wiring diagrams must be submitted.

   i. All inter-panel cables must include 10% spare wires.

8. Terminal Blocks:

   a. All control circuit, relaying, metering, and auxiliary wiring must be terminated on suitable terminal blocks. Terminal blocks must be of unit construction and must be grouped and labeled according to their duty with secure tags on each terminal. Terminal blocks must be mounted on corrosion resistant rails complete with end plates and end clamps. In addition, the assembly rails must be sufficient length to allow for the future addition of one terminal block for every five terminal blocks installed by the Design-Builder. All terminal blocks must be suitably identified using lamacoid labels.

   b. Terminal blocks must have an average of at least one spare terminal for every eight terminals used. In addition, a minimum of 10% spare terminals must be provided for every terminal block assembly.

   c. All terminal blocks must suitably support the incoming and outgoing cables, with the individual wires conveniently arranged for connection to the terminal blocks. A minimum of 150 mm clearance must be provided for termination of external cables.

   d. All internal wiring must be trained to one side of the terminal blocks. Where more than one terminal block section is utilized, a consistent practice must be employed. Where screw type terminals are used, ring type connectors with compression wire fittings must be employed. On 750 V_{DC} wiring only screw/ring type connections must be employed except where terminal blocks are used. For 750 V_{DC} wiring terminated on terminal blocks the positive and negative phases must be separated by at least one terminal block position and must employ partitions or end-plate separators between each terminal. All other wiring must use screw, clamping pressure or locking pin and socket type terminations.

9. Nameplates:

   a. The nameplates must be engraved laminated plastic with black lettering on a white background. The nameplates must be self-adhesive.

   b. Unique identification for nameplates will be supplied by the City. The nameplates must be provided for:

      i. Switchgear assembly designation at the front and rear.

      ii. Description at front and rear of each cell.

      iii. Identification of each front panel mounted device.

      iv. Identification of devices inside the cell such as auxiliary relays, timers, switches, fuses, terminal block assemblies, etc.

      v. Mimic bus showing primary device connection points.

   c. The DC switchgear nameplate must include at minimum the following information:

      i. Name of manufacturer

      ii. Manufacturer's type

      iii. Manufacturer's serial number

      iv. Rated voltage

      v. Rated maximum voltage

vi. Rated continuous current

vii. Fault rating

viii. Year of manufacture

ix. Purchaser name and Purchase Order Number

x. Project Name

d. Each switchgear cell and negative cubicle must be identified by an engraved lamacoid nameplate, white face to black core (70 mm x 400 mm) across the top front of the cell and at the rear of the cell. Each relay, test switch, meter, transducer, and required ancillary devices must be properly identified by an engraved lamacoid label, white face to black core. Lettering size must be at least 4 mm. Nomenclature on all nameplates requires approval from the City. Nameplates must be self-adhesive.

10. Each switchgear cell must include the following:

a. Local/remote switch

b. Red (closed) and green (open) light indication

c. Trip and close control switch

d. Direct close key selector switch on feeder breaker cells

e. Line test on/off switch

f. Transfer trip on/off switch

g. Transfer trip bypass switch for complete switchgear lineup

h. 86 lockout relays in appropriate cells

i. Isolation switches for shunt input

I. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

J. The Design-Builder must submit logic drawings for all close, trip, lockouts, interlock schemes, and transfer trips.

6-2.2.4.3 Traction Power Rectifier and Interphase Transformer

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4.4 – "Traction Power Rectifier and Interphase Rectifier".

B. Provide a TPR that is natural convection air-cooled, complete with all equipment from the low-voltage bus work entrance on the RT to the DC switchgear.

C. Provide an interphase transformer that is dry-type and self-cooled, complete with all equipment to connect to the rectifier unit.

D. Ensure that the interphase transformer is located in the same cubicle as the TPR.

E. For each TPR provide auxiliaries, controls, wireways, interconnecting AC buses, enclosures and necessary hardware, wiring and devices from the low-voltage side of the TPR to the DC switchgear.

F. For the TPR provide protection against transient surge voltages on the DC side of the rectifier. If fuses are used in suppression networks, they must be monitored by visual indicators and equipped with indication devices wired to the HMI and SCADA.

G. The Design-Builder must provide a single line display decal of the equipment lineup on the front of TPR cubicles.

H. Ensure that each TPR has a corrosion resistant metal nameplate containing the following information:

1. Name of manufacturer
2. Year of manufacture
3. Serial number(s)
4. Output rated power
5. Output rated voltage
6. Output rated current
7. Overload currents - magnitude and duration
8. Schematic diagram number

I. Construct a TPR assembly in accordance with IEEE 1653.1 Standard for Traction Power Rectifier Transformers for Substation Applications up to 1500 V_{DC} Nominal Output, as modified herein.

J. Ensure that each TPR is an operative assembly, consisting of silicon diodes, internal buses, terminals for connection to external power and control wiring or buses, shunts, base or bleeder load resistors, protective devices, control wiring, terminal blocks, compartments, cubicles and all other necessary accessories.

K. All TPR and interphase transformer assemblies must be identical.

L. The transformer-rectifier unit must be natural convection air-cooled at the heavy traction loading specified.

M. For maintenance, heat transfer surfaces and characteristics must be Designed for easy cleaning and to minimize accumulation of dust and other contaminants expected in the operating environment.

N. Ensure that each leg of the rectifier is equipped with AC/DC surge protection.

O. Ensure that the TPR has N-1 diode redundancy rating.

P. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

Q. All inter-panel cables must include 10% spare wires.

R. The Design-Builder must submit logic drawings for all close, trip, lockouts, interlock schemes, and transfer trips.

6-2.2.4.4 Negative Disconnect Switches

A. The Design guidance for Infrastructure described in this section makes references to HFDG Section 6.2.4.5 – “Negative Disconnect Switches”.

B. Provide a negative DC disconnect switch mounted in a separate cubicle in each TPSS.

1. Install the disconnect switch between the negative return cable and the rectifier negative pole.
2. Ensure that the rating of the disconnect switch is appropriate for the TPSS ratings and the installed environment.
3. Ensure that the disconnect switch has a solid copper blade with silver plated contacts, is manually operated, single-pole and jaw-pressure-type, and has an insulated operating handle.
4. Design the disconnect switch with an interlocking feature to ensure it can be opened only under no-load. The interlocking Design must follow the requirements of HFDG Section 6.2.4.5 – "Negative Disconnect Switch".
5. Provide a green and red indicating light on the front panel of cubicle where:
    a. Green indicates switch open
    b. Red indicates switch closed

C. Provide a simple operation instruction nameplate on the cubicle door.

D. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

E. All inter-panel cables must include 10% spare wires.

6-2.2.4.5 Rectifier Transformers

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4.6 – "Rectifier Transformers".

B. Provide a RT that is dry-type and self-cooled, complete with all equipment from the high-voltage bus work entrance on the transformer to the AC cable connection to the rectifier unit.

C. For each RT provide auxiliaries, controls, wireways, interconnecting AC buses, enclosures and necessary hardware, wiring and devices from the high-voltage side of the transformer to the low-voltage side of the transformer to the rectifier unit.

D. For each RT enclosure, provide doors or panels to ensure access to high voltage and LV terminals.

E. Doors or panels must provide full access to the tap changer.

F. The tap switch must be prevented from being in an intermediate position between taps with an open circuit winding.

G. Ensure that the RT coupling factor is compliant with TP Rectifier and specially the use of an interphase transformer.

H. Ensure that each RT has a corrosion resistant metal nameplate containing the following information:

1. Name of manufacturer
2. Year of manufacture
3. Serial number(s)
4. Output rated power
5. Output rated voltage

6. Output rated current
7. Overload currents - magnitude and duration
8. Schematic diagram number

I. Construct each transformer base from structural steel members suitable for rolling or skidding in any direction.

J. Provide jacking facilities to permit insertion of rollers between the floor and the transformer base.

K. The Design-Builder must Design transformer base mounting using a vibration isolation damper.

L. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

6-2.2.4.6 Rail Ground Switch

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4.7 – “Rail Ground Switch”.

B. Provide an automatic RGS to survey the rail voltage and connect to ground in case of a non-desirable voltage, if the rail-to-ground voltage exceeds the level of either polarity:

1. Install the RGS between the negative bus and the TPSS ground;
2. The Design-Builder must ensure that the rating of the RGS is appropriate for the TPSS ratings and the environment in which it is installed; and
3. The Design-Builder must provide a simple operation instruction nameplate on the cubicle door.

C. The RGS must consist of a thyristor solid state switch paralleled with a contactor to provide continuous current support.

D. The RGS must be Designed to withstand the maximum current (by magnitude and duration) that may occur in a worst-case ground fault, such as failure on short of a DC surge arrester inside the TPSS.

6-2.2.4.7 Auxiliary Power Supply System

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.4.8 – “Auxiliary Power Supply System”.

B. The 125 V_{DC} auxiliary power supply must provide uninterrupted protection and control power for the TPSS equipment including relaying and communications equipment. The power supply consists of a battery bank, charger, and DC distribution panel.

C. DC Distribution Panel

1. The DC distribution panel connects the battery bank to the charger and various loads. The panel must consist of two-pole DC circuit breakers, one of which is the main incoming breaker from the battery bank and one is the connection to the charger.
2. Each breaker must be two-pole to allow isolation of both the positive and negative circuits under faulted or open circuit.
3. The main breaker must be equipped with a status contact connected to the SCADA system.
4. The busbar must be tin plated copper.

5. Breakers must be bolt on type.

6. Supporting calculations for the minimum fault interrupting capable value must be submitted.

7. All breakers must be minimum 250 V_{DC} rated.

8. Each breaker must be lockable in the off position for maintenance.

9. The breaker panel must have a hinged lockable door.

10. The breaker panel must be suitable for surface mounting.

11. The breaker panel must be a sturdy, rigid chassis assembly to allow accurate alignment of interior and panel front. The panel must be Designed to prevent flexing and minimize possibility of loosening or damage to current carrying parts during and after installation.

D. DC Battery and Battery Charger

1. The battery system must conform to the requirements of CEC, Section 14: Requirements for Batteries.

2. Each DC battery system and charger for TPSS on the mainline and at the Llew Lawrence OMF must be Designed to account for load from both substation and all DC contactors and ground switches within the Llew Lawrence OMF building.

   a. The battery bank size must be Designed and calculated to provide load demand for 8 hours during a total power loss. Calculations must be submitted for review.

3. Provide batteries that are Designed to provide float service under normal usage for the intended duty cycle.

4. Size battery capacity in accordance with IEEE 1189.

5. The charger must be equipped with two-pole input and output breakers.

   a. Battery charger must be temperature compensated.

6. The battery bank must be of modular design and mounted on the substation floor.

   a. Batteries single cells must be sealed valve regulated lead-acid.

7. All battery connections must be insulated and shielded by protective covers to prevent accidental short circuits.

8. The battery rack must be Designed so that batteries from any position within the rack can be easily removed with minimal impact to the adjacent batteries.

9. The battery charger must be equipped with alarm contacts (one normally open and one normally close) that indicate:

   a. Charger fail

   b. AC fail

   c. Battery voltage high (adjustable from 130 to 160 V_{DC})

   d. Battery voltage low (adjustable from 105 to 125 V_{DC})

e. Positive ground (adjustable 1.0 to 5.0 A)

f. Negative ground (adjustable 1.0 to 5.0 A)

g. Battery high temperature alarm and trip

10. Each alarm must be equipped with an individually adjustable delay of 2 – 30 sec.

11. The Design-Builder must provide the battery bank with a stainless steel nameplate with the following information:

    a. Name of manufacturer

    b. Battery and cell type

    c. Month and year of manufacture

    d. 1 min, 1 hr, and 8 hrs amperage rating

    e. Ampere-hour (Ah) capacity of C/8 (8 hours) and C/10 (10 hours)

    f. Accessories

12. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

13. All inter-panel cables must include 10% spare wires.

14. The Design-Builder must submit logic drawings for all close, trip, lockouts, interlock schemes, and transfer trips.

6-2.2.5 TPSS Status and Control

A. The TPSS Status and Control must be integrated in a dedicated HMI, as per HFDG Section 6.2.5 – “TPSS Status and Control”.

B. Each TPSS Status and Control must be capable of being:

    1. performed remotely;

    2. performed locally; and

    3. connected to a third party.

C. Remote control and monitoring of the substation equipment must be provided from both the HMI and the SCADA headend system, by ensuring that:

    1. When the local/remote switch on each of the AC/DC switchgear cubicle is set to “local”, the switchgear operation is controlled locally only. Neither SCADA nor HMI is able to send control commands to the switchgear.

    2. The SCADA local/remote option is managed by the HMI levels and access permissions.

    3. All switchgears which have been set to “remote” at equipment level are controlled remotely from the SCADA headend or the HMI.

    4. Operational command of switchgear from SCADA headend is valid only when both TPSS equipment and HMI have been set to “remote”.

D. The PLC and RTU combined system must be Designed to integrate and control all switchgear functions, system monitoring and data logging in accordance with the requirements of HFDG Section 6.2.5.1 – "TPSS PLC and Local HMI Annunciation".

E. The PLC and RTU combined system must be the SEL RTAC 3350.

F. The PLC and RTU must interface with hardwired devices via a SEL Axion 2240.

G. All intelligent electronic devices, including the AC and DC feeder relays, capable of time synchronization must be compatible with the TPSS master-clock. Precision time protocol is preferred, when not available IRIG-B or network time protocol may be considered respectively.

H. The new PLC and RTU combined system must be fully compatible and interchangeable with existing TPSS Status and Control.

I. The Design-Builder must ensure that the PLC and RTU combined include all the necessary hardware and software to ensure a fully operational coordinated system.

J. The Design-Builder must provide a PLC and RTU combined equipment-based control and interface system for the TPS.

K. The Design-Builder must submit a full TPSS input and output list that defines all controls and status.

L. The list must define control and status points, method of communication if not hardwired, and if local and remote status or control is required.

M. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

N. All inter-panel cables must include 10% spare wires.

O. The Design-Builder must submit logic drawings for all close, trip, lockouts, interlock schemes, and transfer trips.

6-2.2.5.1 TPSS PLC and Local HMI Annunciation

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.5.1 – "TPSS PLC and Local HMI Annunciation".

B. The Design-Builder must provide an HMI touchscreen display for local control and visualization of equipment within the TPSS.

C. The Design-Builder must ensure that the HMI displays a mimic of the TPS being monitored, providing clear displays, and facilities for easy operation and monitoring.

D. The Design-Builder must provide password protected login credentials based on the following levels and access permissions:

   1. Administrator – full access rights including ability to reset lower-level access credentials. This must include the ability to create new levels of access and logins.

   2. Viewer – ability to view information only.

   3. Maintenance – full access to all functionalities, but with no ability to reset credentials or create new logins.

E. The Design-Builder must ensure that the different levels and access permissions determine the local and remote functionality.

F. The Design-Builder must ensure that the HMI display system has capacity for all control and monitoring points, with an additional 25% local I/O expansion capacity at each TPSS.

G. The Design-Builder must submit an I/O schedule for the HMI display system.

H. The Design-Builder must submit a PLC and RTU combined equipment-based control and interface system for the TPS.

6-2.2.5.2 SCADA RTU

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.5.2 – “SCADA RTU”.

B. The Design-Builder must provide the TP SCADA System and ensure that it is fully integrated with all related TP equipment and systems specified within the TPSS via a mix of serial hardwired, ethernet, and fibre communication links to the PLC and RTU combined equipment.

   1. Ethernet communication should be used wherever practicable.

   2. The ethernet communication to the equipment isolated from the ground (e.g., DC switchgear) must be isolated.

   3. The communication protocol within the TPSS must be IEC 61850 Edition 2.

C. The Design-Builder must provide a PLC and RTU combined equipment-based control and interface system for the TPS.

D. The Design-Builder must ensure that the TP SCADA System has sufficient capacity for all control and monitoring points for future integration with the Capital Line LRT TPS in accordance with Section 1-1.4 [*Integration with Capital Line LRT*].

E. The Design-Builder must ensure that the TP SCADA System has capacity for all control and monitoring points, with an additional 25% local I/O expansion capacity at each TPSS.

F. The Design-Builder must prepare and submit an I/O schedule for the TP SCADA System (the “Traction Power SCADA System I/O Schedule”).

G. The Design-Builder must base the TP SCADA System architecture on PLC and RTU combined network to micro-processor based protective relays, intelligent electronic devices, and other smart substation components to facilitate distributed monitoring and control of the TPSS.

H. The TP SCADA System must be Designed to facilitate all control and monitoring functions that can be integrated into a future Internet Protocol based system.

I. The Design-Builder must ensure that the PLC and RTU combined equipment is able to connect to the EDTI control center and allow EDTI to monitor the status of and control various TPSS devices following the requirements of HFDG Section 6.2.5.2 – “SCADA RTU”.

6-2.2.6 Protection System and Devices

A. The Design-Builder must prepare and submit the DC and AC protection coordination studies and short circuit analysis as per HFDG Section 6.2.6 – “Protection System and Devices”

B. The new AC and DC relays must be fully compatible and interchangeable with existing TPSS relays.

6-2.2.6.1 AC Switchgear

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.6.1 – "AC Switchgear".

B. AC relays must be SEL 751.

6-2.2.6.2 DC Switchgear

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.6.2 – "DC Switchgear".

B. DC relays must be Siemens MDC.

C. For re-close of the DC feeder breakers after the main DC circuit breaker is opened due to a momentary fault, the following conditions apply:

   1. The re-closing and lockout of a DC breaker must follow the HFDG Sections 6.2.7.2 – "Line Test and Circuit Re-closing (DC Feeder Breaker)" and 6.2.7.10 – "DC Switchgear and Rectifier Frame Fault Protection".

   2. In the event of a trip due to a momentary fault, a predetermined number of automatic line tests must be made to re-close the circuit if the voltage between the positive catenary line and negative rails through a resistance bridge exceeds a pre-set value.

      a. The settings will have to be aligned with existing system and ensure consistent re-close logic.

   3. If the re-close attempts fail, the re-closing relay must lock out.

D. The Design-Builder must ensure the main DC circuit breaker can be operated to isolate the transformer-rectifier unit in case of an internal fault while allowing continuity of the overhead distribution system.

E. The Design-Builder must submit a DC protection study that incorporates the protection features listed above and is aligned to the philosophy and approach that has been Designed for the Project.

F. DC main breakers must have over and under voltage protection as described HFDG Section 6.2.7.8 – "Over Voltage and Under Voltage Protection (DC Main and Feeder Breakers)".

6-2.2.7 Protection Relay Description

6-2.2.7.1 Reverse Current Protection

A. The Design-Builder must provide reverse current detection for the main DC breaker as per HFDG Section 6.2.7.3 – "Reverse Current Protection (DC Main Breaker)".

B. The protection must detect current flow from the distribution bus into the rectifier unit and trip and lock out the main DC and AC circuit breakers.

6-2.2.7.2 Transfer Trip Protection

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.7.16 – "Transfer Trip Protection".

B. The Design-Builder must provide and install fibre optic cable as the communication media between TPSS for transfer trip function including the existing Century Park TPSS in accordance with Section 1-1.4 [*Integration with Capital Line LRT*] of this Schedule. The transfer trip must:

1. provide interface to and termination of the fibres for a complete operating transfer trip function;
2. monitor the condition of the fibre optic cable continuously;
3. generate an alarm and send to the SCADA if a fault condition is detected;
4. initiate direct transfer tripping between adjacent feeder breakers; and
5. initiate tripping of the remote active breaker feeding the same section when tripping of a DC breaker occurs.

C. The Design-Builder must test the transfer trip in bypass mode, which must include:

1. With new Twin Brooks TPSS in bypass mode, test the transfer trip between existing Century Park TPSS and the new Anthony Henday TPSS.

D. Provide two types of transfer trip operation and integrate into the Project protection coordination scheme as follows:

1. The first type must be automatically resettable. Automatic resetting must be controlled by the load measure re-close relay and occurs on di/dt faults;
2. The second type must trip the DC lockout relay in the originating substation only requiring a manual reset, and is required for DC instantaneous over-current, frame faults, rail-to-ground potential faults, incomplete sequence faults, and emergency shutdown.
3. The Design and Construction must avoid any nuisance trips.
4. Fibre optic monitoring and transfer trip must be integral to protection relays;
5. In all circumstances, the adjacent TPSS breaker must only be tripped to isolate the fault and should not be locked out.

E. The Design-Builder must provide two types of transfer trip architecture and integrate into the Project:

1. Active transfer trip through the communication network done with GOOSE messaging.
2. Direct transfer trip through dedicated and direct fiber connection between the adjacent TPSS' done with mirrored bits.
3. Both architectures must be deployed and tested, including the fallback from active to direct transfer trip.
4. Both architectures must be triggered by the same input for the bypass operation in case the TPSS is out of service.
5. The tie-in at Century Park TPSS must be ensured for both architectures.

6-2.2.8 Rail Bonds/Cross Bonds

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.12 – "Rail Bonds/Cross Bonds".

B. The Design-Builder must provide impedance bonds between each set of adjoining track circuits, with center taps and high current carrying cables to carry the TP return current from track to track and back to the TPSS rectifiers. This includes rail bonding required for special trackwork installations, such as track crossovers and restraining rail installations.

C. Cross bonding between rail and track is required at TPSS locations and at midway points between TPSS.

6-2.2.9 Medium Voltage AC Power Cables

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.13 – "Medium Voltage AC Power Cables".

B. MV power cables and cable termination

1. The Design-Builder must provide MV cables and MV AC switchgear equipped for receipt of three core power cables or three single-core cables in accordance with IEEE C37.20.2.

2. The MV AC infeed supplies to a UC must comply with the Customer Connection Guide.

6-2.2.10 Electrical Switches

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.14 – "Electrical Switches".

B. Feeder and tie switches

1. The Design-Builder must provide feeder and tie switches mounted in a separate cubicle in each TPSS:

   a. Feeder switches must be installed between the DC switchgear and the OCS or between the DC switchgear and the disconnect switches.

   b. Tie switches must be located on the load side of feeder switches. Tie switches are normally open switches that can be closed to tie two adjacent catenary circuits together.

   c. The Design-Builder must ensure that the rating of the feeder and tie switches are appropriate for the TPSS ratings and the environment in which they are installed.

   d. The Design-Builder must ensure that feeder and tie switches have a solid copper blade with silver plated contacts, are manually operated, single-pole and jaw-pressure-type, and have an insulated operating handle.

   e. The Design-Builder must Design feeder and tie switches with an interlocking feature to ensure they can be opened only under no-load.

   f. The Design-Builder must provide a green and red indicating light on the front panel of cubicle where:

      i. Green indicates switch open

      ii. Red indicates switch closed

   g. The Design-Builder must provide a simple operation instruction nameplate on the cubicle door.

   h. Feeder and tie switches should be equipped with frame fault protection (grounded frame and hot structure for stand-alone units only).

2. The Design-Builder must submit layout, mechanical, control schematic and wiring drawings.

3. All inter-panel cables must include 10% spare wires.

4. The Design-Builder must submit logic drawings for all close, trip, lockouts, interlock schemes, and transfer trips.

6-2.2.11 Cable Splices and Terminations

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.2.16 – “Cable Splices and Terminations”.

B. The Design-Builder must ensure that each switchgear assembly has adequate space for termination of power cables to feeder circuit breakers entering from below or above.

    1. The Design-Builder must provide appropriate means for supporting and connecting cables at terminals. The cable entry cover plate must be bolted to permit field drilling of holes for conduit entry.

C. All TP cabling must be run as contiguous cables lengths with no splices or junctions.

D. The Design-Builder must provide gland plates, where required that are equipped for receipt of all control and auxiliary multicore and multipair cables.

E. The Design-Builder must ensure that all TP cables are suitable for the application and rated for the appropriate load and fault current, and where applicable, the de-rating effects when multiple cables are grouped together, and have insulation selected to ensure that emission of harmful products is avoided in any underpass or building locations through the use of low smoke zero halogen cabling.

    1. When low smoke zero halogen cable is installed in locations subject to ultra-violet radiation, mechanical protection must be provided to protect the cable.

F. The Design-Builder must provide a label at each end of each TP cable.

G. The Design-Builder must provide special cables for sections in the 23 Avenue Underpass, as defined in the HFDG for Tunnel applications according to NFPA 130.

6-2.3 OVERHEAD TRACTION POWER SYSTEM

6-2.3.1 Overhead Contact System

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.1.1 – “Overhead Contact System”.

B. The OCS must:

    1. Include all interface equipment between the DC TP supply equipment at the TPSS and the pantograph equipment on the LRVs, including foundations, poles, cantilevers, span wires, supports, system conductors, registrations, droppers, jumpers, terminations, tensioning devices, sectioning equipment, and any other equipment for the operation and maintenance of the LRT System to the requirements as described in the HFDG and this Schedule.

    2. Include all equipment to interface with the Capital Line LRT.

    3. Be Designed and use components similar to and interchangeable with those utilized on the Capital Line LRT which minimize its visual impact along the LRT corridor.

    4. Be double-insulated to create a safe working zone between energized and grounded equipment.

    5. Provide uninterrupted current collection by all LRV pantographs for the operating speed range along the relevant section of the LRT corridor.

6. Operate without fault or failure under the dynamic pantograph characteristics created by the Capital Line LRVs.

7. Conform to the SUI requirements as described in Section 2-1 [*General Sustainable Urban Integration Requirements*] of this Schedule.

C. The traction current return from the LRVs to each TPSS must be via any combination of running rails and parallel underground cables.

D. In the 23 Avenue Underpass, a minimum 3.0 m separation to any installation (cable trays, conduits, antennas, etc.) on the ceiling from the OCS must be provided.

6-2.3.2 Design Requirements and Criteria

A. All OCS drawings submission must follow the requirements of Schedule 4 [*Design and Construction Protocols*].

B. The Design-Builder must submit an OCS Design Drawings comprised of site-specific and OCS layout plans (the "OCS design package"):

1. Site-specific plans must:

a. Include sectionalizing diagrams – schematic single line drawings that show the location of the TPSS and the sectioning requirements of the OCS that enable OCS section isolation in the event of a fault or for routine maintenance. The negative circuit does not need consider those circuit elements required for train signaling purposes.

b. Include master overlap charts – single line diagrams drawn to an approximate along-track scale.

c. Provide OCS layout drawings matching the track alignment baseline and identify the OCS tension lengths. The layout drawing must identify pole IDs with respect to the chainage, contact wire height, messenger wire height, contact wire stagger. The layout drawings should, where possible, physically display stations, crossovers, bridges, road crossings, tunnels and portals.

d. Locate all physical tension lengths on the OCS layout drawings identifying pole IDs, respective termination type and location of mid-point anchors.

e. Provide a legend for the OCS wiring layouts.

f. Show all wire run lengths on the master overlap charts tabulated on a wire run chart drawing.

g. Include OCS wiring layouts using scaled track plans as a background.

i. Show OCS equipment on a pole-by-pole basis, including the dimensional requirements to enable the installation of the OCS to line and elevation. Where poles are not practicable, use alternative OCS support designs, and give the same type details. Supplementary plans may be referenced, as needed.

h. OCS layout plans must include:

i. OCS Standard Plans

i.) General drawings

ii.) OCS abbreviations, drawing legends and general notes in general drawings

ii. Technical Sheets

i.) Provide OCS technical sheets with Design information including parameters, values conductor characteristics, conductor tensions, temperature conditions, maximum wiring spans on tangent and curved track, along-track movement data, wind blow off data, maximum mid-span offset, pantograph clearance envelope and steady arm dimensional criteria.

iii. General Arrangement Drawings

i.) Show layout and dimensions on the general arrangement drawings for poles and wiring at overlaps, mid-point anchors, crossovers and terminations and show multiple poles and multiple spans. Reference typical structures, constrained corridors, and typical spans.

iv. Typical Structure Drawings

i.) Provide elevations on typical structure drawings of typical OCS supports used for various common functions. Show typical heights and staggers of conductors and typical offsets of poles at track cross-sections on the drawings.

ii.) Identify generically the assembly drawings required for complete installation of the site-specific structure.

v. Typical Span Drawings

i.) Provide elevations of typical single spans of OCS wiring, including those with any special features such as section isolators or out-of-running cut-in insulators on span drawings.

ii.) Identify generically the in-span assemblies required in the spans, and where required, set out dimensions.

vi. Assembly Drawings

i.) Assembly drawings are common configurations of OCS components, such as cantilevers, balance weight terminations, down-guys, and poles.

ii.) Rationalize OCS assemblies and provide discrete assembly references by components used and their count – pipe, wires, and tie-wraps need not be counted or dimensioned.

iii.) Provide typical component details of the assembly references allocated on the wiring layouts to illustrate on the assembly drawings and quantify the materials required at each support location.

iv.) Provide components and parts drawings for all the OCS assembly materials. All the relevant ratings for the components and parts must be clearly listed and identified.

C. Final Design

1. The Design Data must align with the requirements of the HFDG and adhere to standards that are indicated and shown in the OCS technical sheets, wiring layouts, arrangements and assembly drawings that are packaged for Design completion, including As-Built and Record Drawings and other generated documents.

a. Responsibilities for completion of the OCS Design must include the following:

i. the preparation of As-Built and Record Drawings for all assembly references, components, and materials;

ii. IFC drawings applying the materials, assemblies, and methods to the OCS Design Data; and

iii. OCS Design for staging work, including preparation of drawings showing interim OCS installations in support of construction staging.

D. As-Built and Record Drawings

1. The Design-Builder must ensure that the component and equipment suppliers have a minimum of 10 years’ experience in the manufacture of OCS hardware for use on LRT systems.

a. The Design-Builder must prepare detailed As-Built and Record Drawings to identify the physical size, strength, form and fit of the assemblies, and the individual components, for each assembly reference used in the wiring layouts.

2. As-Built and building Record Drawings must show the precise quantity of each component required for each assembly in its materials list.

a. Use the assembly references as the basis to prepare As-Built and Record Drawings.

b. Where appropriate, assembly or component weights, dimensions, maximum working loads, and installation rules must be provided.

c. Show registration assemblies pantograph clearance envelope to verify adequate mechanical clearance to pantographs.

E. Installation Documentation must

1. Show the materials schedule and installation procedure, including the assembly references, on the OCS wiring layouts and for the final permanent OCS. The documents provided must include:

a. OCS poles, guys and foundations;

b. OCS pole ID and all attachment point ID (arms);

c. OCS supports, including cantilevers, insulators, cross span wire supports and their mounting brackets;

d. OCS support attachments at overhead bridges and on retaining walls. In tunnels or underpasses, and at other positions where standard supports or structures cannot be installed, special attachments must be designed;

e. OCS conductor termination assemblies including balance weight terminations, fixed termination assemblies and mid-point guy assemblies;

f. Section isolators, jumpers and in-span assemblies;

g. Grounding and bonding; and

h. Incidental OCS system hardware, including safety screens.

F. Contract As-Built Records

1. The Design-Builder must provide As-Built documentation for the final OCS configurations in accordance with Schedule 4 [*Design and Construction Protocols*].

G. Installation Tolerances

1. The Design-Builder must ensure the final installed OCS conforms to the dimensional requirements with the following tolerances:

a.	Contact wire height, at support	±25 mm
b.	Contact wire height, at a bridge	±10 mm
c.	System Height	±50 mm
d.	Dropper length	±5 mm
e.	Contact wire stagger at registration	±10 mm
f.	Messenger to contact wire lateral displacement at support	±25 mm
g.	Vertical separation between crossing messenger wires	±100 mm
h.	Wire tension	±100 N

6-2.3.2.1 Contact Wire Height

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.3.9 – “Contact Wire Height”.

B. The contact wire height set by the Design-Builder must comply to the minimum contact wire height as specified in CSA C22.1-18 and do not exceed the maximum working height of the pantograph for the LRV.

6-2.3.2.2 Contact Wire Gradient

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.3.10 – “Contact Wire Gradient”.

B. The contact wire gradient set by the Design-Builder must comply with the maximum gradient as per CSA C22.3 No. 8, Railway Electrification Guidelines. The gradient must not exceed 2.0% (1:50) under any circumstances. The maximum gradient change from one span to the next must not exceed one-half the maximum gradient for the maximum design speed of the applicable span.

6-2.3.3 OCS – General

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.4 – “OCS – General”.

B. The Design of the transition of the OCS from the existing 4/0 AWG contact wire supported by a 500 kcmil messenger wire and a 500 kcmil parallel messenger wire is open to innovation and may include a transition to a new single 350 kcmil contact wire supported by a single messenger wire. If used, the new 350 kcmil wire must be run to the end of the extension.

C. 23 Avenue Underpass and Anthony Henday Drive LRT Bridge

1. At the 23 Avenue Underpass the messenger wires must dead end on both portals and bridge faces.

2. At the face, the messenger wires must transition to insulated standoffs attached to the structure while the contact wire transfers to elastic arms allowing the wire to remain auto-tensioned and move both horizontally and vertically.

3. At the TUC, the Design-Builder must verify the latest track alignment and crossing of the 500 kV AltaLink Transmission lines as follows:

   a. verify clearances and identify any conflict;

   b. meet clearances per AltaLink requirements;

   c. submit an EMI report based on the latest inputs of the Project and AltaLink line to confirm and mitigate the risks to LRT operation;

   d. if absolute OCS height must be reduced at the crossing, the Design must ensure OCS sections maintain relative height while avoiding steep gradients; and

   e. a crossing agreement between the Design-Builder and AltaLink must be obtained to permit the LRT crossing, as per Schedule 28 Part 2 [*Utility Matters*].

D. Safety Screens

1. The Design-Builder must provide CEC compliant screening or fencing in areas where the OCS wires pass within a 3 m radial clearance from an accessible space, including any adjacent building, bridge, or structure.

E. The Design-Builder must provide OCS insulator composition in alignment with the Capital Line LRT as specified in the Approved Products List.

6-2.3.3.1 Tensioning System in Use

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.4.1 – "Tensioning System in Use".

B. The catenary tension must be calculated to obtain the maximum span as described in Section 6-2.3.4.2 [*Span Lengths*] of this Schedule, respecting the deflection limits.

C. Some auto-tensioned sections may require a tensioning device at one end and a fixed end at the opposite end because of constraints such as roadway intersections, crossovers, and transitioning from the existing end of line to this new extension.

D. Simple catenary auto-tensioned system

1. The OCS should be a simple catenary auto-tensioned system consisting of:

   a. A 350 kcmil solid grooved hard drawn alloy 80 (ASTM B9) copper magnesium ($CuMgO_2$) contact wire.

   b. A 500 kcmil bare, concentric lay, 37 strand hard drawn copper messenger wire. The conductor should have a nominal diameter of 20.65 mm (116.2 mils) and a nominal cross-section area of 253 mm2 (500 kcmil). The overall wire should be of Class B construction in accordance with ASTM B8-04.

6-2.3.3.2 Wire Tensioning Equipment

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.4.3 – "Wire Tensioning Equipment".

B. The OCS wires may be auto-tensioned by external BWA or spring tensioners providing a constant catenary tension throughout the full operating temperatures experienced in the Edmonton region, according to HFDG Section 1.3.20 - “Local Climactic Conditions”.

C. At track crossovers/turnouts, BWA or spring tensioners paired with fixed end must be used.

D. The contact wire and any messenger wire must be maintained at a constant tension using a tensioning device which incorporates safety features to prevent unauthorized persons from accessing the system and must limit the tampering risk.

E. Balance Weight Assembly

1. For maintainability, a BWA must be installed outside the OCS poles.

2. Balance Weight Terminations

a. Performance Requirements

i. Maintain the BWA constant tension in the conductors notwithstanding changes in ambient, solar, or current heating temperatures. As the catenary conductors change in length due to changes in conductor temperature, the balance weight unit/stack must be free to rise and fall.

i.) Operate the BWA freely under all climatic conditions within the auto-tensioned limits specified and function freely when a weight differential of plus/minus 10 kg is applied directly to the stack.

ii.) BWA assembly cable and wire rope terminations must not interfere with the pole, brackets and/or small part steelwork throughout the entire vertical range of up and down movement of the assembly.

ii. Ensure that all wire ropes are non-rotating stainless steel.

iii. Provide compact weights allowing the required total vertical movements to occur in the required temperature range.

iv. Ensure that the BWA have a minimum service and design life, as defined in HFDG Section 1.3.5 – “Service Life and Design Life”, and do not require periodic maintenance or inspection at intervals of less than 12 months.

v. The Design must permit field disassembly and reassembly of an in-place unit by maintenance personnel.

vi. Design the BWA assemblies and component parts for ease of maintenance, replacement, assembly, and disassembly which must be accomplished with a minimum of special tools. Component parts must be individually identified for this purpose.

vii. Incorporate assembly provisions for adjustment due to wire elongation or creep.

viii. Ensure that all BWA materials and equipment are service proven in LRT systems operating in a climate similar to Edmonton. They must be suitably designed for the purpose for which they are intended and be totally compatible for the loads and climatic conditions.

3. General

   a. Operate the catenary system balance weight anchor assembly at a nominal pulley ratio of 1:3.

   b. Use caged element needle bearings for the pulley assembly. Permanently seal the bearings to prevent the ingress of moisture or other contaminants, or the loss of lubricant. Provide grease nipples to permit field replenishment of lubricant during maintenance.

   c. Balance weights must be housed outside OCS poles.

   d. Fabricate balance weights from cast iron.

   e. Weight sets may be either one casting or made up of individual castings.

      i. If individual castings are used, they must be of an interlocking design to prevent slippage. The assembled stack of weights must be as compact as practicable. Maximum weight for an individual casting is 20 kg.

   f. Ensure that the tolerance on weight of the complete balance weight stack is 0 kg to +10 kg.

   g. Ensure that all external ferrous parts are stainless steel or hot-dip galvanized in accordance with the appropriate ASTM specification.

      i. Any ferrous parts, which are not stainless steel or cannot be galvanized, must be painted with an Accepted epoxy coating with colour to match ANSI #61, light gray.

   h. Ensure the name of the manufacturer or trademark and year of manufacture are clearly and permanently imprinted on each tensioning device.

F. Spring Tensioners

   1. Spring tensioning devices should be used where practicable to enhance SUI.

6-2.3.3.3 Mid-Point Anchors

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.4.4 – “Mid-Point Anchor”.

B. To control longitudinal movement while maximizing wire lengths, a fixed mid-point anchor assembly must be used where practicable in the center of each OCS wire section. The opposite end of the wire section must be auto-tensioned with a BWA or spring tensioner on either end.

C. The Design-Builder must provide a mid-point anchor assembly to prevent longitudinal movement of the OCS along the track.

   1. Mid-point anchor must be placed as close as practicable to the midway point between each set of tensioning devices. Maintain minimum separation of 150 mm between messenger and contact wire at midspan to accommodate dropper wires if applicable.

6-2.3.3.4 Terminations or Dead Ends

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.4.5 – “Terminations or Dead Ends”.

B. Complete OCS terminations with a tensioning device anchor pole or a fixed termination pole.

   1. Anchor points or fixed termination points must be placed on the outside of the OCS poles.

2. Pneumatic or hydraulic tensioning devices are not permitted.

C. Cable Termination

1. Furnish the line and load side disconnect switch terminals with silver plated copper buses complying with ASTM B187, to accommodate the number and size of copper cables.

a. Each line and load side of switches must accept at minimum six 500 kcmil, NEMA 2-hole lugs. Factory supplied and installed cable openings must be provided for all cable sizes/openings and must be fitted with weatherproof cable bushings for all entries and exits.

6-2.3.4 Overhead Contact System Configurations

6-2.3.4.1 Tension Length and Tension Section

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.5.1 – “Tension Length and Tension Section”.

B. Tension Section

1. Catenary sections should be based on typical maximum 800 m auto-tensioned wire sections. Various elements on or near the LRT ROW may limit the tension section Design, including:

a. Station locations (transitions should be avoided);

b. road and pedestrian crossings (transitions should be avoided);

c. special trackwork or crossovers; and

d. track curvature (transitions should be avoided in horizontal and vertical curves).

C. Divide the OCS into tension sections with each tension section having an overlap with each adjacent section. Insulate the overlaps between adjacent tension sections at TPSS locations to provide isolation points. Transition/overlaps must not be used in curved and gradient sections.

6-2.3.4.2 Span Lengths

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.5.2 – “Span Lengths”.

B. The maximum Design span must be 58 m for single catenary.

C. Messenger sag charts must be submitted by the Design-Builder.

1. Messenger sag must consider expansion due to both environmental conditions and electrical loading.

6-2.3.4.3 System Depth

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.5.3 – “System Depth”.

B. The typical system depth is 1600 mm as measured between the messenger wire and contact wire at support locations.

6-2.3.4.4 Contact Wire Stagger

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.5.4 – "Contact Wire Stagger".

B. The contact wire must be staggered (stitched) +/- 200 mm from either side of center of track to maintain good current collection and uniform wear of the pantograph carbons. The stagger for curved track may be up to +/- 250 mm.

C. This stagger must take into consideration conductor blow off, contact wire height, span lengths, pole deflection, vehicle dynamics, width and sway of pantograph, along-track conductor movement, track tolerances, and installation tolerances.

D. Stagger the contact wire on both tangent and curved tracks to achieve uniform wear of the pantograph. Where messenger wire is required, stagger the contact wire and position the messenger wire over the contact wire.

E. Prepare and submit an OCS pole placement and stagger report based on LRV parameters and specifications.

   1. Prepare the report in accordance with Good Industry Practice.

   2. The report must include the maximum span length and stagger (i.e., fewest number of support structures) required to ensure that pantograph dewirement does not occur.

6-2.3.4.5 Overlap Transition Spans, Crossovers, and Turnouts

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.5.6 – "Overlap Transition Spans, Crossovers, and Turnouts".

B. OCS Jumpers

   1. Ensure that continuity jumpers in auto-tensioned contact wire are of a length and configuration appropriate to the differential movement of the conductors.

      a. Calculate the lengths of the jumpers based on field measurements.

   2. Install jumpers to avoid conflicts with the uplifted pantographs, adjacent cantilevers, cross contact bridges and droppers.

   3. Ensure that the cut end of jumpers does not project more than 25 mm through the connection clamps. Wrap the ends of all jumpers or fit with a barrel crimp to prevent fraying.

      a. Electrical taping of the ends of jumpers is not permitted.

   4. Install connection clamps in accordance with manufacturer's recommendations.

      a. Before fitting the connector clamps, clean and wire-brush the conductors to ensure a good electrical connection beneath the clamp and lubricate with a conductive grease as recommended by the manufacturer.

   5. The connector bolts must be torqued to manufacturer's recommendations using a calibrated torque wrench.

   6. Mark all bolted clamps and connections after final torquing to indicate completion.

6-2.3.5 Overhead Contact System Support Components

6-2.3.5.1 Poles

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.6.1 – “Poles”.

B. The OCS poles proposed for this Project should be galvanized straight steel octagonal poles, similar to poles installed on recent Edmonton high floor LRT projects.

  1. Alternative pole types may be considered, including H-section, provided the sizing and applicable lifespan criteria are the same. All poles must be hot-dip galvanized steel, and any drilling on site is prohibited.

C. There are four different classes of poles proposed for use in this Project.

  1. “T” Tangent – Poles used to support typical catenary on a tangent section of track.

  2. “C” Curve – Poles used to support typical catenary in areas with curved rail with a radius of 200 m to 800 m.

  3. “D” Dead end – Poles that terminate tensioned wires. May also support a tensioning device.

  4. “F” Feeder – Poles that allow the TP feeder cables to run inside the pole to the catenary wires above.

D. Each pole type must be designed to be bonded to a dedicated local ground rod or set of ground rods.

  1. The ground Design for the poles must conceal ground cable as much as practicable to mitigate the possibility of theft.

     a. The Design must consider the solutions presented in Appendix 6A and Appendix 6B, however alternative designs will be considered for approval as innovations.

E. The OCS Designs may include downhaul anchors to support the dead end poles which may reduce the pole size and strength required.

F. Use cross spans or head spans between two OCS poles to support the OCS where a pole cannot be placed between the tracks or where the distance between the track and the nearest OCS pole is too great.

G. Llew Lawrence OMF Tie-In

  1. South of the Anthony Henday Drive LRT Bridge as the track returns to grade, the alignment passes the north entrance into the Llew Lawrence OMF. With the narrow track spacing through this area, center poles must support mainline as well as the turnout into the facility.

H. Heritage Valley North Station

  1. The poles must be located on the west side of the track as the alignment approaches the diamond crossover.

  2. Through the diamond crossover, the poles must transition to the outside of the alignment.

I. 41 Avenue SW Extension Transition

  1. To allow for the transition to a future extension of the Capital Line LRT south of Ellerslie Road SW, a set of dead end poles and anchors must be placed at the end of line that optimize future

connections and cutovers. Specifically, dead end poles in the future trackway alignment should be avoided if practicable.

J. OCS Poles

1. This section covers the design, fabrication, hot-dip galvanizing, painting and labeling of new octagonal steel poles for use as part of the OCS as specified herein.

2. The OCS poles may be of an octagonal steel-galvanized type in accordance with ASTM A123.

3. Pole Design must comply with the SUI requirements in accordance with Schedule 4 [*Design and Construction Protocols*] and the HFDG.

4. Pole Types

   a. Octagonal poles matching those currently in place on the Capital Line LRT may be used.

      i. Balance weight anchor poles may be straight and not tapered.

K. Poles General

1. Poles must:

   a. Provide a contemporary, unadorned Design at minimal height and diameter. Heavier wall thickness section poles and or other visually unobtrusive structural reinforcement innovations must be utilized to achieve minimal pole diameters.

   b. Have a Design bending capacity based on the yield stress of the material.

   c. Deflect no more than 2% of their length when the rated maximum bending load is applied 600 mm from the top of the pole.

   d. Be raked with a tolerance of ±25 mm to appear vertical when under normal dead load conditions (i.e. no wind or ice).

   e. Have a pole cap or finial to prevent water ingress.

   f. Be Designed to prevent water accumulation inside the pole.

   g. Be provided with sealed cable spouts wherever wires or cables exit through the side.

2. Where employed, poles must be Designed such that the BWA are housed outside the OCS poles.

3. Repair any damage to galvanized OCS pole finished surfaces in accordance with ASTM A780.

4. If OCS poles must be combined with lighting, spacing between poles must be optimized with the lighting and catenary Design.

   a. Infill lighting poles may only be considered if it can be demonstrated that lighting levels in pedestrian areas and Roadways cannot be achieved solely through the use of shared use poles.

   b. Shared use poles are only permitted when there is no practicable way to light the trackway, roadway, and pedestrian areas without them.

L. Product Description

1. Fabricate all pole shafts from one structural steel material type conforming to the following requirements:

    a. A595, Grade A steel;

    b. Base plates must be fabricated from structural steel conforming to ASTM – A572, Grade 42 steel; and

    c. Poles must have no spliced joints.

2. Fabricate pole caps from steel compatible with the pole shaft and attached to the shaft with a minimum of three stainless steel set screws.

M. Fabrication

1. Fabricate poles, handholes, fittings, accessories and base plates by methods conforming to AISC specifications, except as specified herein.

2. The following tolerances must be used during fabrication:

    a. Octagonal pole diameter (if applicable): +/-1.5 mm of the design diameter and +/- 1.5 mm of perfectly round;

    b. Pole wall thickness: design thickness to +10%;

    c. Pole straightness: +/-1.5 mm per 1.5 m of pole length; and

    d. Base plate tolerances must be as follows:

        i. Bolt diameter: +1.5 mm, -0 mm

        ii. Hole diameter: +1.5 mm, -0 mm

        iii. Location of holes: ±1.5 mm along the bolt circle diameter

N. Pole Identification

1. Provide pole identification plates following the existing identification system and characteristics of the Capital Line LRT.

    a. Identification number for poles and tunnel arms must be the chainage distance in meters from the zero-datum point at the Churchill Station cavity. Use prefix and suffix letters to denote position and trackage.

    b. Existing chainage system must be continued.

    c. The arm numbering must be Designed to avoid duplicating IDs by using preceding characters to identify the branch of the system and/or using the reference datum point.

2. Locate pole stationing labels at a height to be easily read by a Train Operator travelling in either direction.

O. Pole Finish

1. Poles finishes must be in accordance with the SUI requirements in Part 2 [*Sustainable Urban Integration and Landscape Architecture*] of this Schedule.

2. Ensure that OCS poles are supplied from the manufacturer in a finished condition.

    a. Any finish damage requiring field touch-up must conform to the manufacturer's specifications.

P. Signage

1. Install electrification warning signs after the poles have been installed.

2. Warning signs must match those on the Capital Line LRT.

3. Provide and install the following types of OCS signage on all new or modified OCS poles:

    a. Pole station labels

    b. "Danger – Live Wire"

    c. "Danger – High-Voltage"

    d. "No Trespassing"

6-2.3.5.2 Overhead Contact System Pole Foundations/Anchor Bolts

A. Placement of the OCS poles and supporting structures must be clear of the Vehicle Running Clearance Envelope as well as traffic and pedestrian crossings. These clearance considerations must include all relevant loading conditions that influence the position of the OCS poles and wires.

B. The Design-Builder must construct OCS pole foundations from reinforced concrete, Designed and constructed in accordance with the requirements in Part 4 [*Transportation Structures and Building Structures*] of this Schedule. They must be:

1. embedded in the earth, be an integral part of the track slab structure, or provided as part of other structures forming part of the LRT system;

2. designed to account for the structural loading and soil conditions;

3. designed for the maximum elastic bending capacity of the pole plus 20%;

4. designed to accept a bolted base;

5. designed with separate embedded conduits for pole and, when applicable, surge arrester grounding; and

6. designed to contain feeder or utility cables using concealed conduits.

C. Ensure that all metallic OCS pole foundation components, including the pole baseplates, that are embedded in or otherwise come in contact with concrete surfaces are coated with a sacrificial/barrier coating. The sacrificial/barrier coating must be applied to the entire component and must extend a minimum of:

1. 150 mm into the concrete

2. 25 mm above the surface of the concrete

D. OCS Foundations on Transportation Structures

1. For OCS foundations on Transportation Structures refer to Section 4-3.23 [*Pole Foundations*] of this Schedule.

E. Quality Assurance

1. Construction tolerances

a. Ensure the tops of all foundations and anchors are within ±25 mm of design level.

b. Install OCS foundation anchor bolts plumb and within the following tolerances relative to the top of the foundation:

i. Horizontal: +/-10 mm off of square, the center of which must meet the tolerance requirements of the foundation; and

ii. Vertical: +/-5 mm. Provide templates for all anchor bolts to ensure correct alignment.

2. Measure and record the electrical resistance testing of the pole and foundation grounding systems. Ensure that the OCS poles have a ground resistance of 10 Ω or less.

F. Anchor Bolts

1. Provide high strength carbon steel bolts; ASTM F1554, Grade 55, over-tapped threads in accordance with AISC requirements for UNC Series.

2. Galvanizing must comply with ASTM A153.

3. Nuts must comply with ASTM A563, hot-dip galvanized, over-tapped threads in accordance with AISC requirements for UNC series.

G. Clevis Connector and Coupler Sleeve

1. Ensure the clevis connector and coupler sleeves comply with ASTM A668 and with ASTM A153 for galvanizing.

H. Ground Wire

1. Ensure that ground wires comply with ASTM B3 annealed, soft drawn, bare copper, of Class B strand, with 98% conductivity.

2. Ensure that the ground wires comply with the requirements of the CEC.

a. Ground wires must, at a minimum, be 2/0 AWG bare.

I. Exothermic Welding Material

1. Exothermic welded type connections (Cadweld or equivalent) should be used.

a. Materials, including molds, weld material, tools and accessories, must all be supplied by one manufacturer to ensure compatibility.

b. If mechanical connections are used, they must be compression type.

J. Foundation Ground Rods

1. Ensure that the foundation ground rods are in accordance with Section 6-2.3.6.7 [*Structure Grounding and Bonding*].

2. Perform electrical resistance testing of all OCS foundation grounds in accordance with Section 6-2.3.6.7 [*Structure Grounding and Bonding*].

6-2.3.5.3 Cantilever Arm Assemblies

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.6.2 – "Cantilever Arm Assemblies".

B. Provide cantilever arm assemblies to vertically support the OCS along at-grade sections of the LRT alignment.

   1. The cantilever arm assemblies must vertically support, and horizontally regulate the contact wire and any messenger wire.

   2. Cantilever arm assemblies must be mounted directly to the OCS poles by brackets.

6-2.3.6 In-Span Assemblies

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7 – "In-Span Assemblies".

B. All OCS electrical equipment must have double insulation rated at a nominal 1.5 kV_{DC}.

   1. At any support a minimum of two levels of electrical insulation, with at least 1.8 m separation between energized and grounded ends, must be provided between the contact wire and a line pole or other grounded structure.

C. Any uninsulated metalwork located within 600 mm of an OCS conductor or support must be screened using insulating material.

6-2.3.6.2 Feeders

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7.4 – "Feeders".

B. If the OCS configuration in the Reference Design is implemented, the Century Park southbound positive feeder must power two different catenary configurations; this will require the Design-Builder to reassess the protection settings for the DC feeder breakers in the existing Century Park TPSS.

C. Positive and Negative Feeders

   1. At each Station, the positive feeder poles must be placed such that optimal support to the trains is achieved, with section isolators placed to minimize wear during normal train direction operation.

   2. The negative cables must run from the substation to the impedance bond then to the rails.

6-2.3.6.3 Electrical Switches

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7.5 – "Electrical Switches".

B. Provide disconnect switches in fibreglass cabinets inside the TPSS.

   1. Local controls, located in lockable enclosures, must be provided for maintenance activities.

C. Ground mats are required at all disconnect switch operating handle locations.

D. Disconnect switches must be suitably rated switches to connect/disconnect two adjacent electrical sections of OCS.

E. General

1. The outdoor type pole mounted DC disconnect switch must be a single throw, no-load break and non-fusible air switch, with motorized/manual operator.

2. Comply with the applicable requirements given in ANSI C37.34 and Z55.1, ASTM B187, NEMA 250, SG 5, ICS 1, and ICS 2.

3. Pole mounted disconnect switches in NEMA 3R non-metallic, outdoor type enclosure are acceptable.

4. Ensure that all exposed unit outdoor switches are capable of operation with a 5 mm thick covering of glazed ice on the external switch mechanism and operating rods.

5. Bolt cable terminations using cable lugs.

    a. Lugs, unless otherwise indicated, must be tin plated copper, long-barrel, compression type, two-hole, with NEMA hole sizes and spacing and complying with UL 486A for voltages up to 35 kV.

    b. Insulate lug terminations with insulated sleeves.

F. Provide switches rated for 1 kV_{DC} continuous (825 V_{DC} nominal) operation with 3.7 kV, Root Mean Square (RMS), minimum insulation level.

1. Continuous current ratings must be 2 kA without exceeding a 50°C rise above a maximum ambient temperature of 40°C.

2. Switches must have a momentary current withstand rating of not less than 100 kA RMS for 50 ms.

G. Two-Pole Switch Operation

1. Ensure that two-pole switches are switching both positive and negative polarities of their connected circuits.

    a. In the normally closed position, the positive pole must connect to the positive supply. In the open position, the positive pole must connect to a grounded connection.

    b. The positive switch pole must operate in a break-before-make sequence, with component clearances factory set to mitigate the risk of electrical flashover in the known conditions of service and environment.

    c. The negative switch pole must be connected in the closed position to the traction current return path. In the open position this pole must be connected to a grounded connection.

H. Manufacture

1. Ensure that the moving and stationary switch contact surfaces are silver plated copper.

    a. All other current carrying parts must be of high conductivity copper or copper alloy. Contacts must be self-aligning, wear compensating, and with initial wiping action.

2. Ensure bus conductors are of a high conductivity electrical grade copper.

3. Manual Operation of Disconnect Switch

    a. The bus must be tin plated copper and rated for a continuous current of 4000 A_{DC}.

b. Each line disconnect switch must be electrically interlocked with the associated circuit breaker to ensure that the switch cannot be operated when the breaker is in closed position.

    i. Each feeder disconnect switch must be provided with a 125 V_{DC} solenoid. The solenoid must be wired in series with a normally closed contact of the associated circuit breaker auxiliary contact to achieve the interlocking. The solenoid must be normally in the 'inoperable position' and must become operable when energized. The solenoid and the circuit breaker auxiliary contacts must be compatible.

c. Furnish each pole mounted or wall mounted switch with an insulated operating rod, with an operating handle mounted at operator height from ground level on an OCS pole.

d. Furnish operating handles with heavy duty lugs to accept padlocks in the fully open and closed switch positions. Indicate switch positions with 'open' and 'closed' signs, or easily visible indicators or markings.

e. Configure the switch operating rod and handle such that the operating pipe is in its lowest position and the handle is down in the 'open' position.

    i. Each switch must be housed in an enclosure and must be equipped with a pivot mounted, permanently attached, insulated spade handle that swings away from the switch. The enclosure door must be able to be closed with the switch in the 'open' or 'closed' positions. Ensure the operating handle is capable of withstanding stresses of multiple openings and closings.

    ii. Hot-dip galvanized steel or stainless steel is required for all non-current carrying metal parts. All external enclosure fasteners and hinges must be stainless steel.

I. Switch Enclosures

1. Ensure that non-metallic fibreglass switch enclosures are of a ventilated, raintight, tamperproof design as per NEMA 3R rating.

    a. The enclosure must have a gasketed, heavy duty hinged door with padlockable handle, catch, full length hinge (one sided) and hooded ventilation openings with screens.

    b. Each switch set must have galvanized steel angles attached to the top and bottom suitable for wall mounting the equipment.

2. Provide one specified outdoor type padlock with each cabinet (enclosure), all keyed alike.

3. Cells must be equipped with a hinged door with a latching mechanism to allow full access to the switch and bus work contained inside.

4. Provide a dead front operating handle and inside the box for each switch. The switch position must be visually indicated by the handle alignment with open and closed plates.

5. All switches must have an explosion-proof viewing window allowing a clear view of the entire switch.

6. Ensure that the enclosure is of sufficient size to accommodate the switch, internal linkages and operating gear, cabling and terminations without electrical shorting or damage due to chafing on the feeder cable insulation.

    a. All maintainable components must be readily accessible through the door opening, and sufficient space must be provided for the manipulation of required tools.

7. Equip the exterior face of the cabinet with a switch data/nameplate and a “Danger - High-Voltage” warning label permanently attached to the cabinet.

8. A warning sign with white lettering on red background must be fastened to each switch with 8 mm lettering that reads “CAUTION - DO NOT OPERATE LINE DISCONNECT SWITCH UNLESS ASSOCIATED CIRCUIT BREAKER IS OPEN”

9. Provide mimic bus to represent the power flow through the switches.

10. Ensure that the enclosure is a minimum of 5 mm thick polyester with a glass to resin ratio of 40 to 60 and is equipped with a drain hole in the base.

    a. Resin must be fire retardant polyglass or equal as Accepted by the City.

11. Padlocks

    a. Provide each pole mounted disconnect switch operating handle with an outdoor type, heavy duty, keyed padlock having a hasp diameter of 50 mm minimum.

    b. All padlocks must be keyed alike.

    c. Provide two keys to the City for each padlock.

6-2.3.6.4 Section Isolators

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7.6 – “Section Isolators”.

B. Section isolators may be used for Yard Track, Lead Track, Shop Track, crossover OCS sections, and Mainline Track where overlaps are not practicable.

C. Design of the isolation points must take into consideration the highest risk locations for degraded operations to optimize use of platforms when short turning and when interfacing with replacement bus services.

D. Locate section isolators so that the DC power from the TPS can be supplied independently to the line segments on either side of each TPSS.

    1. Section isolators must not be located at accelerating zones and must be suitable for maximum operating speed in both directions.

E. Section isolators must be supported using double arm supports. An arm is required on either side of the section isolator to provide adequate support.

6-2.3.6.5 Splices

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7.7 – “Splices”.

B. Splices must not be used in new cables, conductors, wires, and ropes.

    1. With the exception of the OCS messenger and contact wires, splices may be used, as Accepted by the City, when connecting to the Capital Line LRT system.

6-2.3.6.6 Surge Protection

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7.9 – “Surge Protection”.

B. Surge Arresters

1. Provide and install surge arrester assemblies at locations including:

    a. OCS poles with positive feeder cable risers;

    b. OCS poles with pole mounted disconnect switches;

    c. OCS poles which are on either side and/or under all overhead bridges crossing the LRT corridor; and

    d. on poles at a maximum spacing of every 300 m.

2. Each surge arrester must be suitable for OCS pole mounting and supplied with accessories.

3. The grounding installation for the surge arrester must be exclusive.

    a. Where present on the same structure, the OCS and surge protection ground systems must be tied together below grade, after the grounding resistance is measured and confirmed individually.

4. Each grounding installation must have a maximum grounding resistance of 5 Ω or as specified by the surge arrester manufacturer for the type of unit supplied, if less than 5 Ω.

6-2.3.6.7 Structure Grounding and Bonding

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 6.4.7.10 – “Structure Grounding and Bonding”.

B. Provide common grounding of OCS support poles on the bridges through electrical connection to each other and an OCS ground electrode system.

C. Grounding and bonding

1. Ensure that conductors for grounding and bonding are ASTM B8, Class B stranded annealed copper.

2. Ensure that bolts, washers, and stop nuts for connectors and clamps are of a high copper alloy, Everdur, Durium, Duronze, or silicone bronze. Ferrous hardware is not acceptable.

3. Provide ground rods that are:

    a. Medium carbon steel core, copper clad by the molten weld casting process with conductivity of not less than 27% of pure copper. The minimum thickness of the copper on the cylindrical portion of the rod must average not less than 0.01 in.

    b. Not less than 3/4 in diameter and 10 ft length. One end must be suitable for compression couplings or threaded for threaded extension couplings.

6-2.4 TESTING AND COMMISSIONING

A. The Design-Builder must perform all tests necessary to ensure that the TPS elements perform according to the requirements identified on this Schedule as per HFDG Section 6.5 – "Testing and Commissioning".

B. The Design-Builder must prepare and submit a complete and comprehensive test plan along with detailed, specific test procedures in accordance with Schedule 6 – Testing and Commissioning.

SECTION 6-3 – SIGNALS

6-3.1 TRAIN CONTROL SYSTEM

6-3.1.1 Infrastructure Description

A. The Signal System enables full bi-directional train operations throughout the track alignment, protects conflicting train movements, ensures train separation, and ensures speed control. It enables the management of train operations from the OCC.

B. The Signal System is comprised of the following main systems and equipment:

1. Train detection based on track circuits
2. A fixed block signal system with a maximum block length of 1000 m
3. A magnetic trip-stop system
4. Speed-check devices
5. Switch Position Indicators
6. A vital logic control system
7. A Centralized Train Control (CTC) system
8. LCPs in each signal room
9. An at-grade crossing system for vehicular and pedestrian crossings

C. The Design-Builder must Design and Construct the Signal System as a safety-critical system as defined in the HFDG Section 7.4.5.2 - "Design".

6-3.1.2 Reference Standards

A. Design guidance for Infrastructure described in this section is provided in HFDG Chapter 7 – "Signals".

B. The LRT Signals system Design must also meet all the requirements of the following:

1. The Edmonton High Floor LRT Signal Engineering Manual, available as Disclosed Data.
2. LRT-COMMS-HDBK-BCP-101 (Best Common Practices for Equipment Racks and Cabinets), available as Disclosed Data.
3. AREMA Communications and Signals Manual of Recommended Practices.

6-3.1.3 Design Requirements

A. The Design-Builder must provide a signaling system for:

1. The Mainline Tracks
2. Yard Track entries/exits to the Llew Lawrence OMF

B. The Signal System must ensure all train movements are possible on the extension for normal, maintenance and emergency operations as described in the Appendix 5-1B.

C. No LRV retrofit is permitted to accommodate the new Signal System.

6-3.1.3.1 Signal Territories

A. The signaling system must be divided into two discrete territories:

  1. the first territory should extend from Century Park to the south end of Anthony Henday Drive LRT Bridge; and

  2. the second territory should extend from the north yard switches of the Llew Lawrence OMF to Heritage Valley North Station.

B. Each signaling territory must be controlled by its own signaling room with a dedicated UPS located in a UC as described in HFDG Section 7.16.3.1 – "Power Back-Up Systems":

  1. the first signal room must be located at the Twin Brooks UC; and

  2. the second signal room must be located at the Heritage Valley North Station UC.

C. All new Signal equipment must be integrated and connected to one of the two new territories.

6-3.1.3.2 Design and Integration

A. The Signal System provided for the Project by the Design-Builder must be identical to the Signal System of the Capital Line LRT and comply with the Edmonton High Floor LRT Signal Engineering Manual included as Disclosed Data.

B. The Design-Builder must fully integrate the Signal System for the Project with the Signal System provided for the Capital Line LRT to prevent operational deadlocking between Century Park Station and Twin Brooks Station.

C. During the tie-in, the Design-Builder must ensure the Signal System stays safe and does not create operational disturbance.

6-3.1.3.3 Design Deliverables

A. The Design-Builder must submit a detailed description of the Signal System Design, track signal plans, track and cable drawings, and the operational description and rationale for the Signal System elements. This submission must include block diagrams, drawings, and schematics to support the narrative. Also required is a description of how locking will be implemented to protect two opposing or flanking trains that are in contention to occupy the same specified limits of track at the same time.

B. The Signal System description must include a functional description document for each application logic and all the acronyms used in each of the Vital logic controller equations.

C. The Design-Builder must prepare and submit to the City an interface control document describing the electrical and functional interface requirements of the Signal System for the OCC integration.

6-3.1.3.4 Track Circuits

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 7.5.1.1 – "Track Circuits".

B. Train detection must be implemented using track circuits to maintain continuity with the Capital Line LRT.

C. The Design of track circuits must consider that a high-voltage power line crosses the LRT ROW north of the Anthony Henday Drive LRT Bridge to not reduce the reliability of train detection at this location.

D. Over the entire CLSE, impedance bonds must be installed on H-beam supports to avoid interference from Traction Power current and water ingress.

6-3.1.3.5 Signal Block and Overlap

A. Protection system and devices must conform to the requirements of HFDG Section 7.5.2 – "Fixed Block Signaling" and the following requirements.

B. Signal Block overlaps must be calculated and optimized by the Design-Builder following the Edmonton High Floor LRT Signal Engineering Manual Section 5.5. For the in-station calculation, a 15 km/h speed mid-station must be used. To avoid over-speeding in-station, speed checks must be installed before and at mid-station.

C. The Signal Block Design Data and optimized overlaps must be reviewed by the City for an assessment of potential compliance with the required 5-minute headways.

6-3.1.3.6 Signal Products

A. The proposed products for the Signal System must be identical to those currently used by the City and must be in accordance with the Approved Products List, when applicable. Any requested deviations from the Approved Products List must be Accepted by the City.

B. Requirements for the LRT Signals include:

1. Vital logic controller must be an Alstom ElectroLogIXS;
2. Custom software LCP control panels must be procured through GE/Alstom;
3. Crossing controllers must be Alstom ElectroLogIXS;
4. Wheel detectors must be Frauscher; and
5. Track circuits must be audio frequency type by GE/Alstom.

C. New equipment or concepts for the speed-check circuit may be considered by the City.

6-3.1.3.7 Centralized Train Control

A. The CTC system must conform to the requirements of HFDG Section 7.12 – "Centralized Train Control" and the following requirements.

B. For the update of the CTC system, Wabtec, previously ARINC, must be engaged to update the ARINC / Rockwell Collins / Wabtec office system for trains supervision as defined in the HFDG Section 7.12 - "Centralized Train Control" and PA/VMS.

C. The update of the CTC is a software and configuration update. No additional physical equipment (screens, storage, servers) is required in the OCC.

D. If necessary, the Design-Builder must adapt the automatic routing system of the Capital Line LRT to account for the Project.

6-3.1.3.8 At-Grade Crossings

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 7.13 – “Intersections: At-Grade Crossings” and the following requirements.

B. The Design-Builder must provide automatic grade crossing warning systems with gates, flashing lights and bells, block signals, call-on signals for all vehicular crossings, crossing warning indicator for all pedestrian only crossings, providing separate gates for pedestrian and vehicular crossings as described in HFDG Chapter 17 – “Streets”, for crossings at the following locations:

1. Century Park Bus Access (No LRT pre-emption interface)
2. Saddleback Road / 19 Avenue and 111 St NW (South ring)
3. 12 Avenue and 111 Street NW
4. North pedestrian access to Twin Brooks Station (No LRT pre-emption interface)
5. 9 Avenue and 111 Street NW
6. Heritage Valley North Park and Ride access

C. All grade crossing warning systems except for the pedestrian access to Twin Brooks Station, Century Park Bus access, and the Heritage Valley North Station access require an interface to the adjacent Traffic Signal System.

D. The operational mode for the Project requires full LRT pre-emption of Traffic Signal operation. The interface between the LRT Signaling system and the affected Traffic Signals is described in the HFDG Section 7.14 – “Intersections: Traffic Signal Interface”. The Design-Builder must Design and Construct this interface.

E. The LRT vital logic controller will provide a pre-emption request to an affected Traffic Controller notifying of an approaching northbound or southbound train, as well as a subsequent notification when the grade crossing warning system is active. The Traffic Controller will provide ‘Health’ indications to the LRT vital logic controller and acknowledgement that the pre-empt requests have been received. All traffic lights must be placed outside the crossing perimeter and meet minimum offsets from the LRT Signals Infrastructure in accordance with the HFDG.

F. The City will provide the Design-Builder with the required pre-emption time that must be used to initiate a pre-emption request at each applicable crossing location.

G. The City will create and implement Traffic Signal timing plans that will support implementation of LRT pre-emption.

H. The design and construction of the Traffic Signal Infrastructure required to both permit implementation of LRT pre-emption and to reflect new roadway geometry at signalized intersections will be undertaken by the City and provided to the Design-Builder for coordination and integration during detailed Design.

SECTION 6-4 – COMMUNICATIONS

6-4.1 INTRODUCTION

A. The requirements contained in this section for the CTS inform the Design, supply, and construction of the communications architecture and all related subsystems for this Project.

B. The CTS Design must meet the requirements in the following:

1. The HFDG Section 8 – “Communications”
2. Edmonton Facility Design and Construction Consultant Manual Volume 2 Technical Guidelines
3. The LRT Communications handbook best common practices

C. If any requirement as specified in Schedule 5 is in conflict, then the most stringent requirement will apply.

D. Any deviation from the HFDG must be identified and submitted for review and approval by the City, as per the Design Development Change Process defined in Section 5.3 of Schedule 13 [*Changes*].

6-4.1.1 Applicable Codes, Standards, Regulations, and Guidelines

A. The Design-Builder must ensure that the communications system, all subsystems, and all associated Infrastructure comply with the following codes, standards, and regulations, to the extent applicable:

1. For CCTV

a. Product safety standards as defined in IEC/EN/UL 60950-1

b. Product safety standards as defined in IEC/EN/UL 60950-22

c. Relevant parts of Society of Motion Picture and Television Engineers 296M (HDTV 720p)

d. Relevant parts of SMPTE 274M (HDTV 1080p)

e. ISO/CEI 23008-2 UIT-T H.265

f. Open Network Video Interface Forum Profile S or ONVIF Version 1.01 or higher as defined by the ONVIF organization

g. EMC approvals: EN 55022 Class B, EN 55024, Federal Communications Commission Part 15 - Subpart B Class A+B, VCCI Class B, RCM AS/NZS CISPR 22 Class B, ICES-003 Class B, KCC KN32 Class B, KN35, KCC KN22 Class B, KN24

h. Mechanical and environmental standards: IEC/EN 60529 IP66/67, ISO 20653 IP6K9K. NEMA 250 Type 4X, IEC/EN 62262 IK10, IEC 60068-2-1, IEC 60068-2-2, IEC 60068-2-6, IEC 60068-2-14, IEC 60068-2-27, IEC 60068-2-78

i. Railway environmental standards: EN 50121-4, IEC 62236-4

j. IEEE standards: 802.3af/802.3at (Power over Ethernet), IEEE 802.1X (Authentication)

k. Internet Engineering Task Force: IPv4 (RFC 791), IPv6 (RFC 2460), QoS – DiffServ (RFC 2475)

l. ANSI/BICSI 002

2. For PA systems and VMS
    a. NFPA 130, Standards for Fixed Guideway Transit Systems
    b. International Electrotechnical Commission
    c. 60268-16 - Objective Rating of Speech Intelligibility by Speech Transmission Index
    d. Canadian Electrical Code - Part I, Part II & Part III
    e. CSA Standards
    f. Electrical and Electronic Manufacturers Association of Canada Standards
    g. Electronic Industries Alliance/Telecommunications Industries Associations:
        i. EIA/TIA RS160-51 – Sound Systems
        ii. EIA/TIA SE103-49 – Speakers for Sound Equipment
    h. IEEE – C62.41 Surge Voltages in Low – Voltage AC Power Circuits
    i. Underwriters Laboratories of Canada Standards:
        i. UL 48 – Standard for Safety Electric Signs
        ii. UL 1433 – Standard for Safety Control Centres for Changing Message Type Electric Signs
    j. ANSI/BICSI 002
3. For telephone systems
    a. Americans with Disabilities Act
        i. 28 CFR Part 36, ADA Standards for Accessible Design
    b. American Society of Mechanical Engineering
        i. ASME A17.1a-2002 - Safety Code for Elevators and Escalators
    c. Federal Communications Commission
        i. 47 CFR Part 68 - Connection of Terminal Equipment to the Telephone Network
    d. American National Standards Institute
    e. Building Industry Consulting Services International
    f. National Fire Protection Association
        i. NFPA 70 - National Electric Code
        ii. NFPA 72 - National Fire Alarm Code
        iii. NFPA 130 - Standard for Fixed Guideway Transit and Passenger Rail Systems
    g. Telecommunications Industries Association

h. Underwriters Laboratories

    i. UL1459 - UL Standard for Safety Telephone Equipment

    ii. UL/CSA 60960 - Safety of Information Technology Equipment

    iii. UL 50, Type 3R - Enclosures for Electrical Equipment

i. ANSI/BICSI 002

4. For radio systems:

    a. GSM alliance standards

    b. ANSI/BICSI 002

6-4.1.2 CTS Conceptual Overview

A. The CTS must conform to the requirements of HFDG Section 8.1.2 – “Communications Systems Conceptual Overview” and the following requirements.

B. The CTS is the communications system that provides connectivity to all the subsystems of the Capital Line LRT. It is based on a common Infrastructure environment that supports core services for the communications network, server computers and centralized storage. The communications subsystems that are connected to the common Infrastructure environment are the following:

1. Operator’s common Infrastructure environment
2. CCTV cameras
3. Radios
4. Telephones
5. Passenger Information
6. Tunnel intrusion monitoring
7. Signalling and train control interface
8. Building Management System monitoring and control interface
9. TP, transfer-trip and EDTI SCADA network interfaces
10. 3rd party advertising and telecom interfaces
11. Corporate IT Network interfaces for fare collection and access control

C. The CTS is used to provide connectivity to all the subsystem on Mainline Track and at the Llew Lawrence OMF.

D. There are three new UC communications rooms for the Project:

1. At Twin Brooks UC
2. At Llew Lawrence OMF UC
3. At Heritage Valley North UC

E. There are a two communication rooms inside the Llew Lawrence OMF building for the Project:

   1. One communications room, for ETS Network;

   2. One main network access room, for Corporate IT Network.

F. The Project Work for the CTS includes:

   1. The Design, manufacture of materials and equipment, fabrication, supply of materials, installation, testing, commissioning, and incidentals necessary to complete the CTS Construction and installation.

   2. Integration of the Project to the Capital Line LRT will be inside the communication room in Century Park Station.

   3. Supply of all communications special tools and spare parts as described in Schedule 4 [*Design and Construction Protocols*] to perform all preventative and corrective maintenance, and repairs.

6-4.2 SYSTEM INTEGRATION

A. Design guidance for Infrastructure described in this section is provided in HFDG Section 8.1.5 – "System Integration" and the following requirements.

B. The tie-in location to the Capital Line LRT ETS Network backbone, access, traffic signals and Corporate IT Network fibre cables are to be in the optical splice enclosure (OSE) [redacted]

C. As detailed in the Table 1-1.3.1 [*City Works*] in Part 1 [*General*], the City will complete the fibre connection from the patch panel in the communication room in the Century Park Station which shall be installed by Design-Builder. The Design-Builder must re-test the fibre cables that were spliced in the OSE and patched to the patch panel demarcation point to ensure their condition before the City completes the connection to the existing network. Design-Builder must hire Chermik Communications Ltd. to perform the tie-in work in Century Park Station communication room for the CTS. The City will provide the following to support the Design-Builder's Design and Construction:

   1. sufficient cable containments connecting communication vault #209 to Century Park Station communications room;

   2. drainage of vault #209, which the Design-Builder will need to incorporate to their roadway drainage Design;

   3. sufficient space at the Century Park Station communications room and equipment to accommodate the works to be done by the Design-Builder; and

   4. record drawings for Items 1, 2, and 3 will be provided to the Design-Builder for use in Design and Construction within 6 months of the Effective Date.

D. The Design-Builder must provide a fibre connection between:

   1. The Llew Lawrence OMF Utility Complex communications room to the Llew Lawrence OMF for Corporate IT Network communications. The fibre must be 48 strands single mode fibre optic cable and be terminated in the main network access room.

   2. The Llew Lawrence OMF Utility Complex communications room to the Llew Lawrence OMF for ETS Network communications. The fibre must be 144 (72 in and 72 out) strands single mode fibre optic cable and be terminated in the ETS communication room.

E. Heritage Valley Transit Centre has 3 x 103 mm underground ducts stubbed out to the property line The Design-Builder install three new 103 mm ducts to continue the stubbed ducts from the Heritage Valley Transit Centre electrical room into the Heritage Valley North UC manhole. The Design-Builder must perform a site investigation to confirm the precise location of the existing ducts.

F. The Design-Builder must install a new OSE and a new fibre patch panel in the Heritage Valley Transit Centre communications room.

G. The Design-Builder must install a new fibre optic splice closure in the Heritage Valley North UC vault.

H. The Design-Builder must install 2 x 24-strand fiber optic cables in one of the three ducts running between the Heritage Valley Transit Centre communications room and the Heritage Valley North UC vault.

I. The Design-Builder must terminate and test the 2 x 24-strand fiber optic cables in the new OSE and the new fibre optic splice closure. The termination in both communications rooms (Heritage Valley Transit Centre and Heritage Valley UC communication room) must be in patch panels (refer to drawing no. D-00-EK-10101 of Appendix 6E [*Communications Design Preliminary Report*]).

J. The Design-Builder must perform Integration activities following City Works activities as described in Section 1-1.3 [*City Works*]:

   1. The Design-Builder must install and connect City supplied ETS Network equipment including routers and switches in the signals and Traction Power rooms as defined in Section 2.3.3 of Appendix 6E [C*ommunications Design Preliminary Report*].

   2. The Design-Builder must provide technical and logistic support regarding end-devices during Integration and Testing performed by the City and Other Contractors.

   3. The Design-Builder must provide technical and logistic support regarding CCTV end-devices and alarms equipment during Integration and Testing performed by the City and Other Contractors.

   4. The Design-Builder must provide technical and logistic support regarding ETS TV Screens during Integration and Testing performed by the City and Other Contractors.

   5. The Design-Builder must provide technical and logistic support regarding advertising end-devices during Integration and Testing performed by the City and Other Contractors.

6-4.3 GENERAL DESIGN REQUIREMENTS

A. The Design-Builder must Design and Construct the communications system in compliance with the Appendix 6E [*Communications Design Preliminary Report*].

B. The Communications Design Preliminary Report comprises:

   1. Technical requirements

   2. High level architecture diagrams

   3. Detailed plans

C. Any Design deviation from the Communications Design Preliminary Report must be identified and submitted for review and approval by the City as per the Design Development Change Process defined in Section 5.3 of Schedule 13 [*Changes*].

6-4.3.1 Signals Communication Network

A. The Design-Builder must Design and Construct the signals communication network in close coordination with the LRT Signals designer.

B. The number of signal bungalows will have an impact of the LRT Signals communication network. The Design-Builder must modify the CTS Design Data to mirror the LRT Signals Design Data.

6-4.4 PREREQUISITES BEFORE CITY WORKS

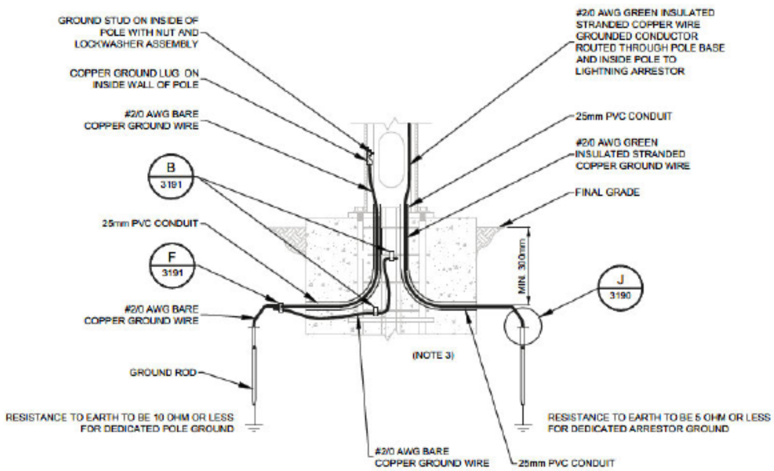
A. The Design-Builder must ensure the availability of stable power for all ETS Network equipment prior to the beginning of the testing and commissioning phase for that equipment; electrical power must be maintained without interruption after the testing and commissioning process is completed; and no power outage may last longer than the amount of time that the communication power system is designed to provide coverage for.

   1. Any work impacting the communication power system after completing the testing and commissioning of the ETS Network and Corporate IT Network requires approval from the City.

B. The Design-Builder must submit a comprehensive checklist for each designated area and subsystem individually, which must be in alignment with the Final Design. This checklist will be subject to the City's Acceptance and should encompass all the conditions and requirements as specified in Appendix 6F.

C. The Design-Builder must complete all work up to the demarcation points as defined in Appendix 6E [*Communications Design Preliminary Report*].

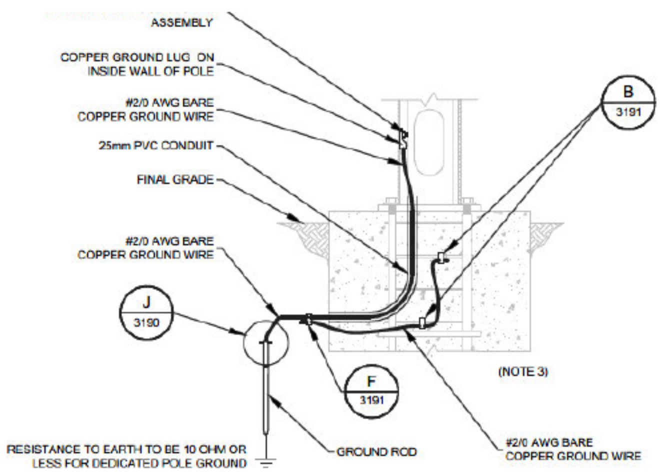
APPENDIX 6A OCS POLE AND SURGE ARRESTER GROUNDING SAMPLE FROM METRO LINE LRT (NAIT-BLATCHFORD) EXTENSION



NOTES:

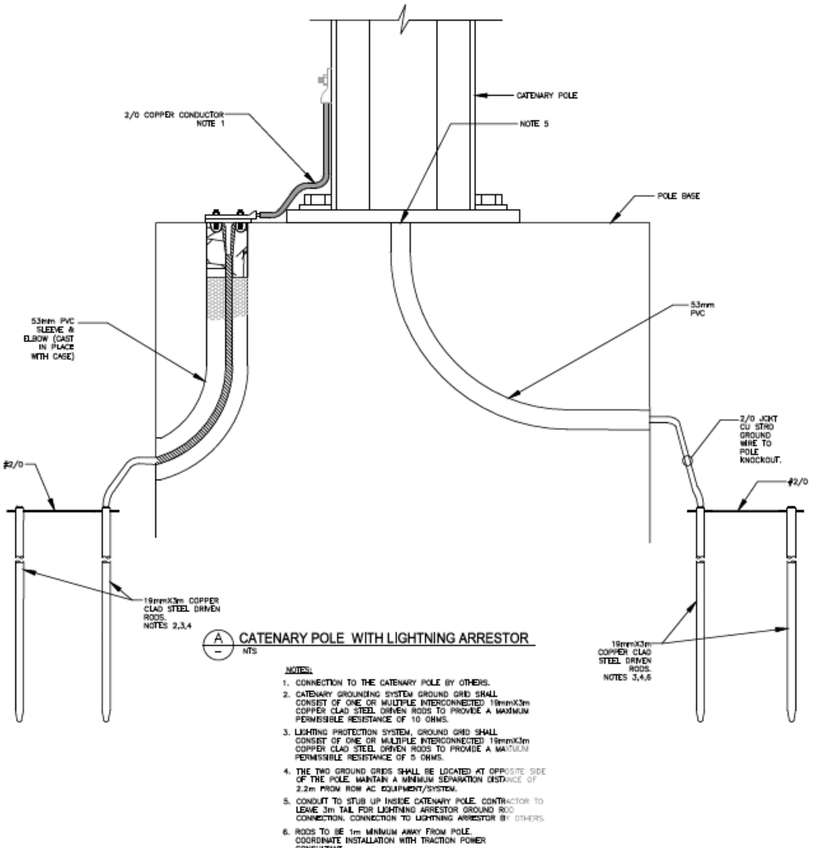
1. RESISTANCE TO GROUND SHALL BE MAXIMUM 5 OHMS FOR LIGHTNING ARRESTERS AND MAXIMUM 10 OHMS POLE GROUND.
2. GROUND ROD TO BE MINIMUM 600mm FROM EQUIPMENT FOUNDATION BASE.
3. BOND REBAR OF OCS POLE BASE IN TWO PLACES TO THE GROUND CONDUCTOR.

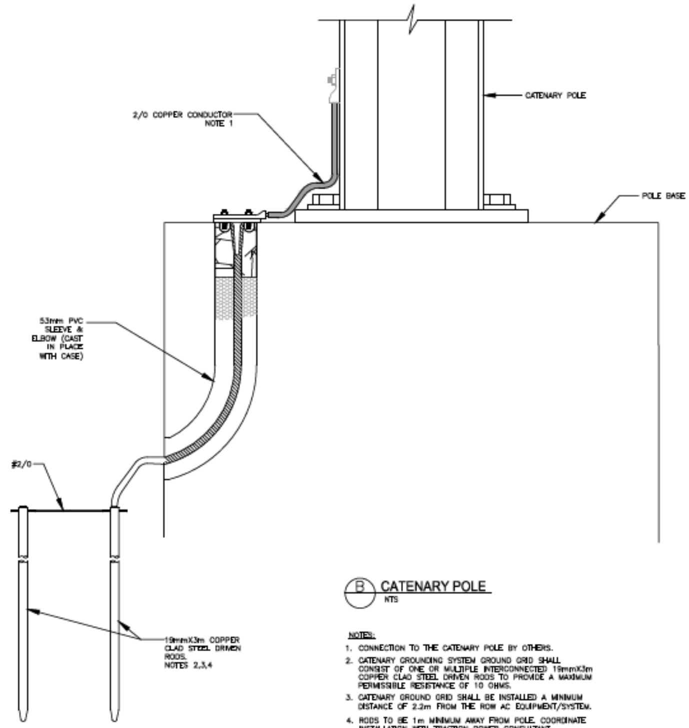
1 - VIEW
TYPICAL BOOSTER POLE GROUND WITH LIGHTNING ARRESTOR GROUND DETAIL



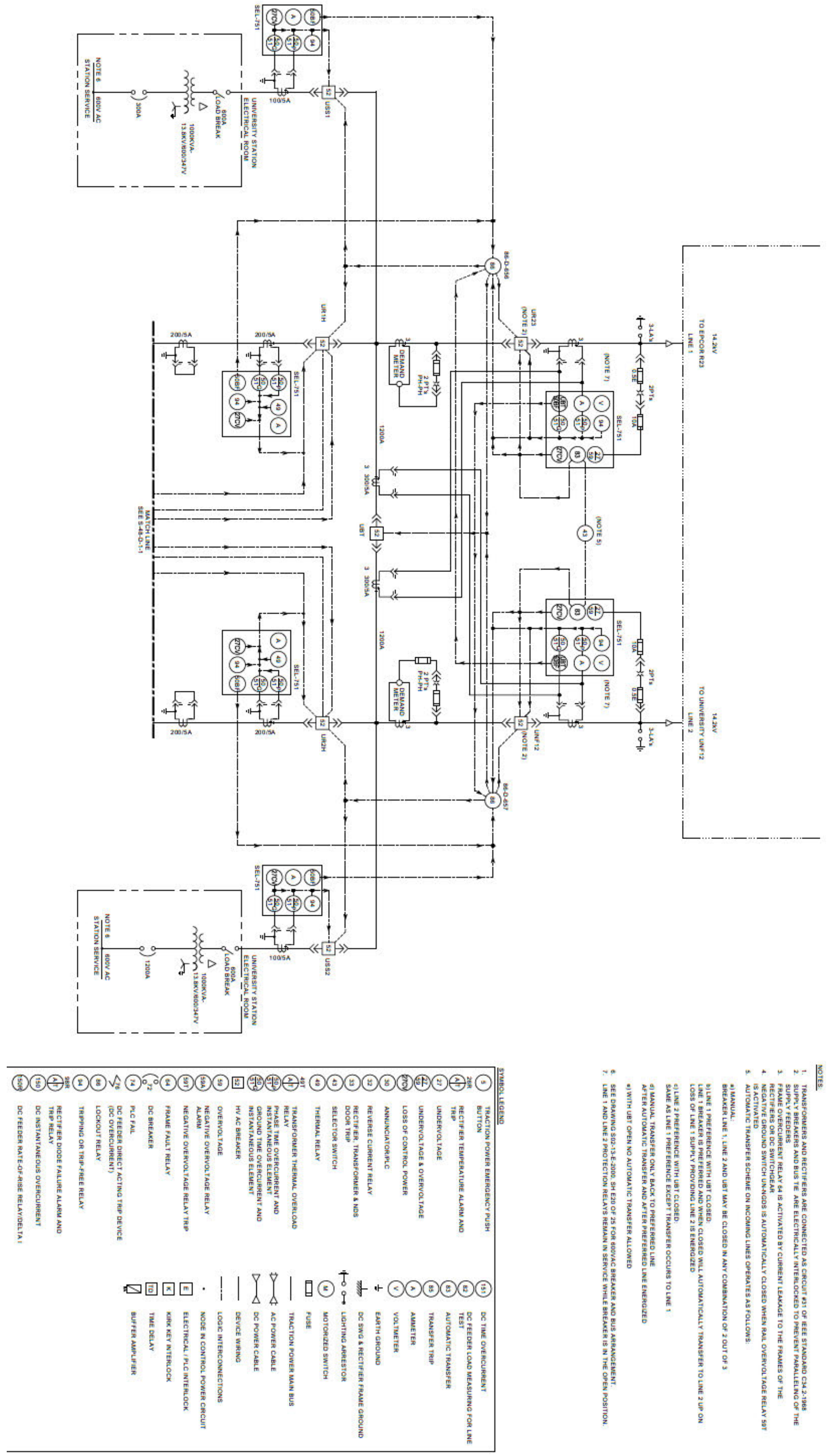
2 - VIEW
TYPICAL CATENARY POLE GROUND DETAIL

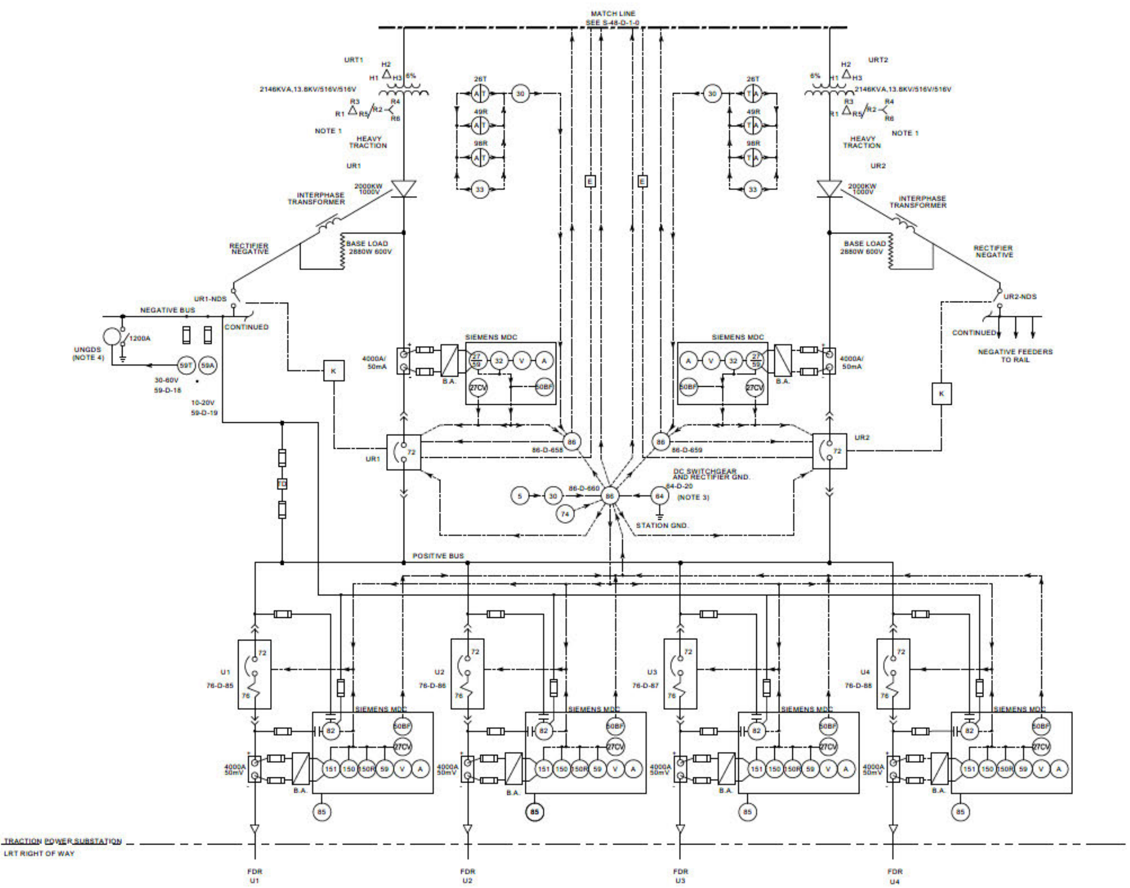
APPENDIX 6B OCS POLE AND SURGE ARRESTER GROUNDING SAMPLE FROM METRO LINE LRT NAIT EXTENSION





APPENDIX 6C UNIVERSITY TPSS: SINGLE LINE DIAGRAM





NOTES:

1. TRANSFORMERS AND RECTIFIERS ARE CONNECTED AS CIRCUIT #31 OF IEEE STANDARD C34.2-1968
2. SUPPLY BREAKERS AND BUS TIE ARE ELECTRICALLY INTERLOCKED TO PREVENT PARALLELING OF THE SUPPLY FEEDERS
3. FRAME OVERCURRENT RELAY 64 IS ACTIVATED BY CURRENT LEAKAGE TO THE FRAMES OF THE RECTIFIERS OR DC SWITCHGEAR
4. NEGATIVE GROUND SWITCH UN-NGDS IS AUTOMATICALLY CLOSED WHEN RAIL OVERVOLTAGE RELAY 59T IS ACTIVATED
5. AUTOMATIC TRANSFER SCHEME ON INCOMING LINES OPERATES AS FOLLOWS:

   a) MANUAL:
   BREAKER LINE 1, LINE 2 AND UBT MAY BE CLOSED IN ANY COMBINATION OF 2 OUT OF 3

   b) LINE 1 PREFERENCE WITH UBT CLOSED:
   LINE 1 BREAKER IS PREFERRED AND WHEN CLOSED WILL AUTOMATICALLY TRANSFER TO LINE 2 UP ON LOSS OF LINE 1 SUPPLY PROVIDING LINE 2 IS ENERGIZED

   c) LINE 2 PREFERENCE WITH UBT CLOSED:
   SAME AS LINE 1 PREFERENCE EXCEPT TRANSFER OCCURS TO LINE 1

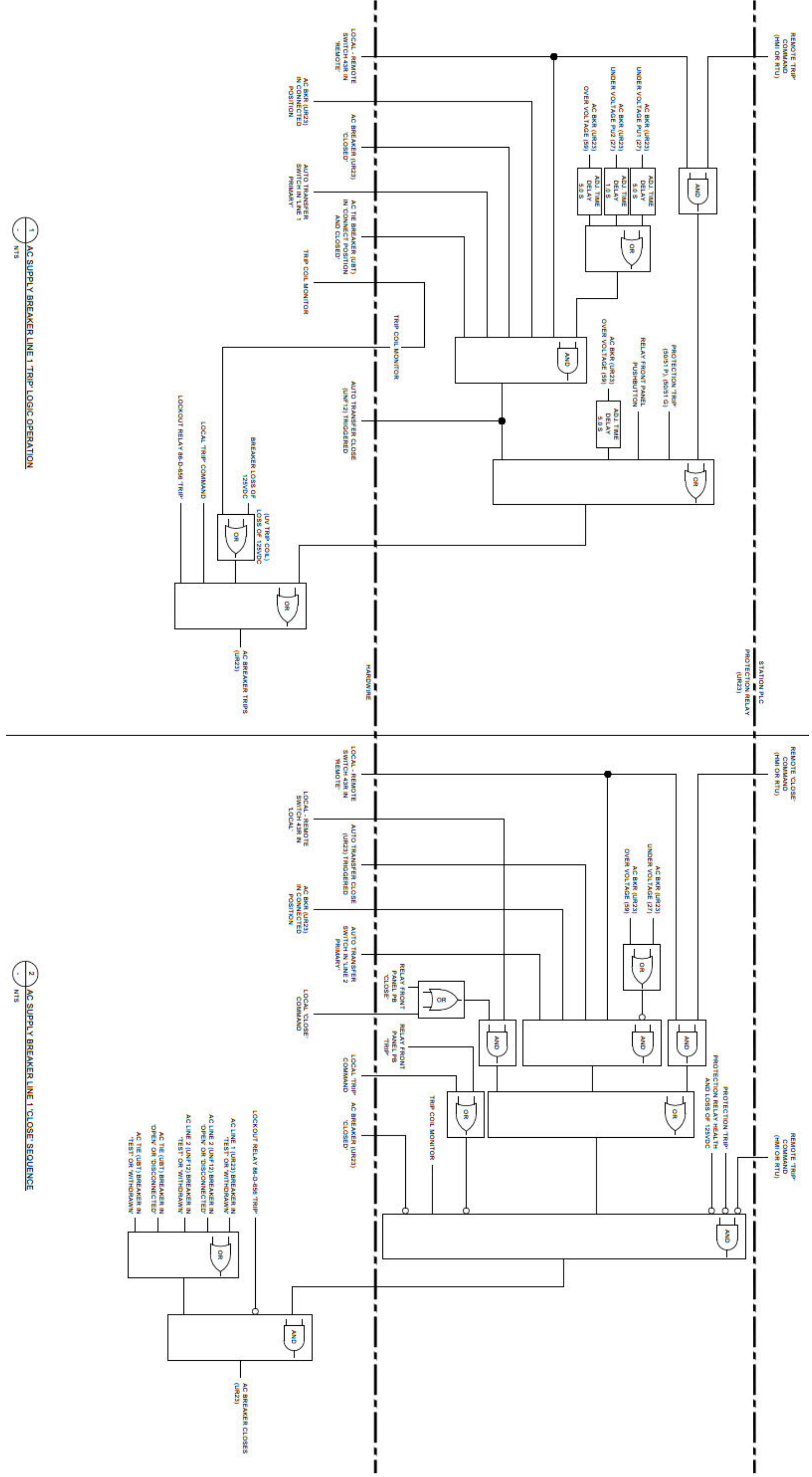
   d) MANUAL TRANSFER ONLY BACK TO PREFERRED LINE
   AFTER AUTOMATIC TRANSFER AND AFTER PREFERRED LINE ENERGIZED

   e) WITH UBT OPEN NO AUTOMATIC TRANSFER ALLOWED

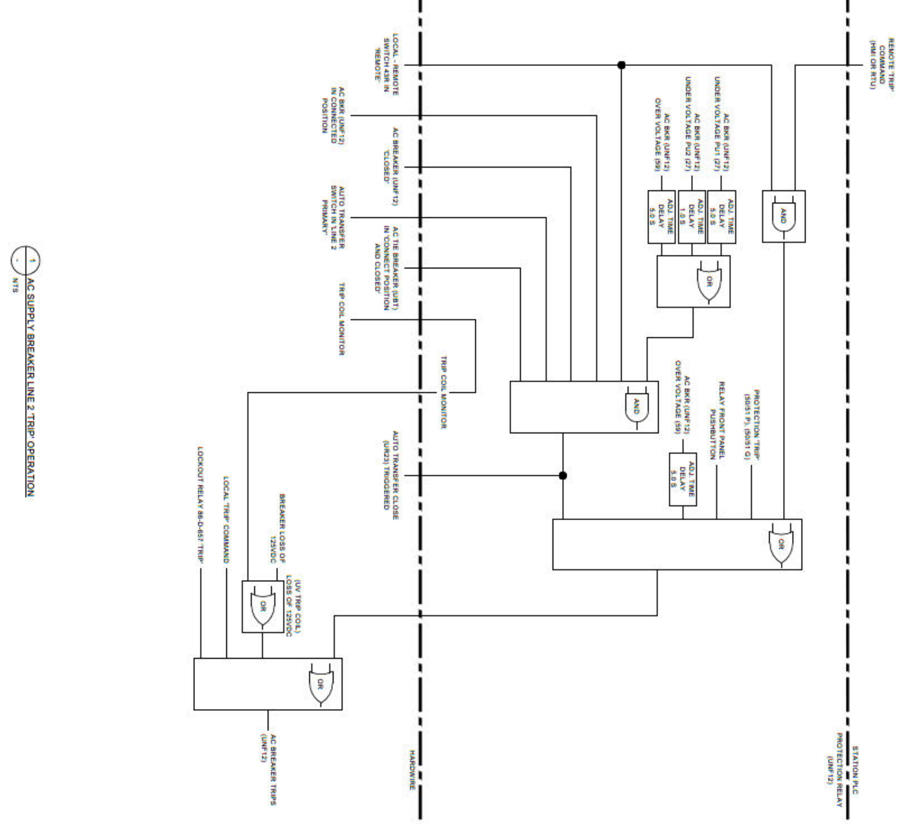
6. SEE DRAWING S02-13-E-2000, SH E20 OF 25 FOR 600VAC BREAKER AND BUS ARRANGEMENT.

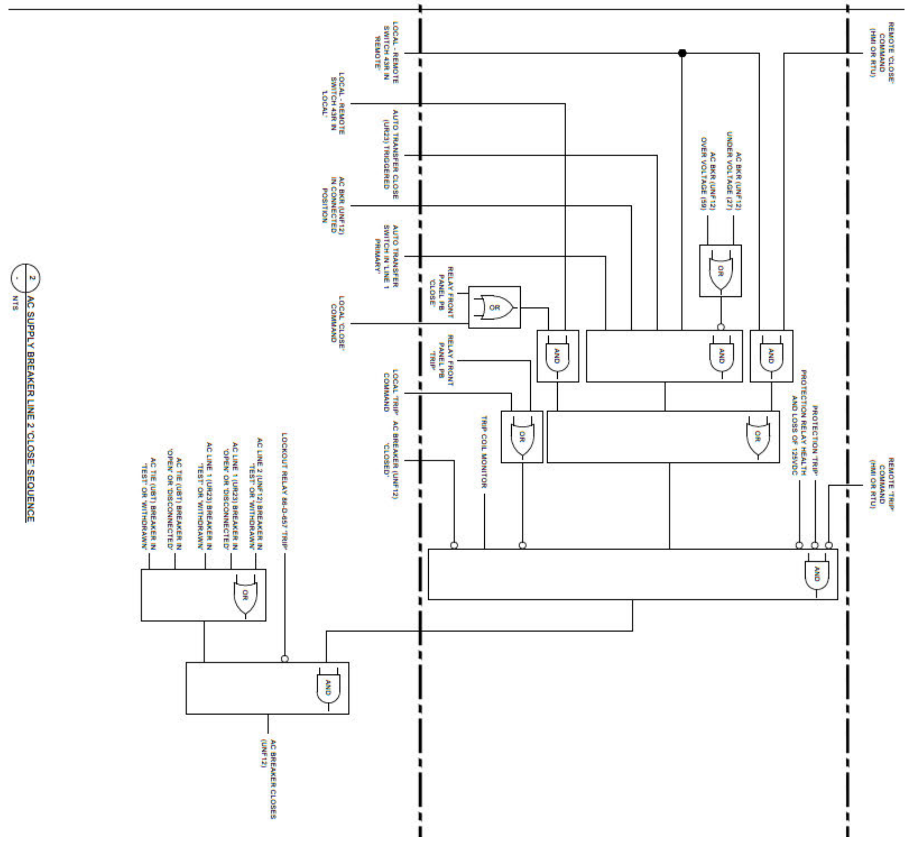
SYMBOL LEGEND

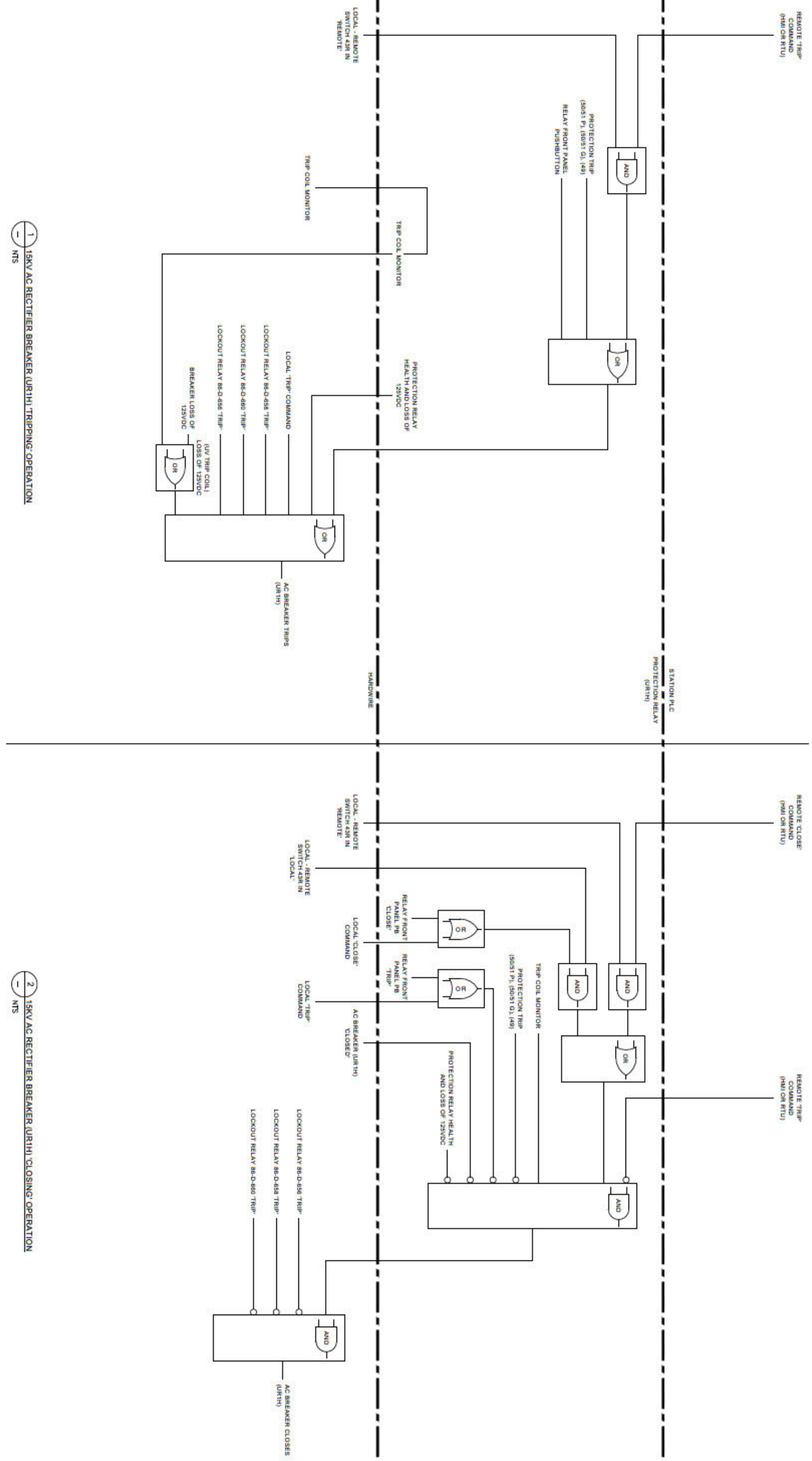
5	TRACTION POWER EMERGENCY PUSH BUTTON	151	DC TIME OVERCURRENT
26R A T	RECTIFIER TEMPERATURE ALARM AND TRIP	82	DC FEEDER LOAD MEASURING FOR LINE TEST
27	UNDERVOLTAGE	83	AUTOMATIC TRANSFER
27/59	UNDERVOLTAGE & OVERVOLTAGE	85	TRANSFER TRIP
27CV	LOSS OF CONTROL POWER	A	AMMETER
30	ANNUNCIATOR / PLC	V	VOLTMETER
32	REVERSE CURRENT RELAY		EARTH GROUND
33	RECTIFIER, TRANSFORMER & NDS DOOR TRIP		DC SWG & RECTIFIER FRAME GROUND
43	SELECTOR SWITCH		LIGHTING ARRESTOR
49	THERMAL RELAY	M	MOTORIZED SWITCH
49T A T	TRANSFORMER THERMAL OVERLOAD RELAY		FUSE
50/51 P	PHASE TIME OVERCURRENT AND INSTANTANEOUS ELEMENT		TRACTION POWER MAIN BUS
50/51 N	GROUND TIME OVERCURRENT AND INSTANTANEOUS ELEMENT		AC POWER CABLE
52	HV AC BREAKER		DC POWER CABLE
59	OVERVOLTAGE		DEVICE WIRING
59A	NEGATIVE OVERVOLTAGE RELAY ALARM		LOGIC INTERCONNECTIONS
59T	NEGATIVE OVERVOLTAGE RELAY TRIP	•	NODE IN CONTROL POWER CIRCUIT
64	FRAME FAULT RELAY	E	ELECTRICAL / PLC INTERLOCK
72	DC BREAKER	K	KIRK KEY INTERLOCK
74	PLC FAIL	TD	TIME DELAY
76	DC FEEDER DIRECT ACTING TRIP DEVICE (DC OVERCURRENT)	B.A.	BUFFER AMPLIFIER
86	LOCKOUT RELAY		
94	TRIPPING OR TRIP-FREE RELAY		
98R A T	RECTIFIER DIODE FAILURE ALARM AND TRIP RELAY		
150	DC INSTANTANEOUS OVERCURRENT		
150R	DC FEEDER RATE-OF-RISE RELAY/DELTA I		

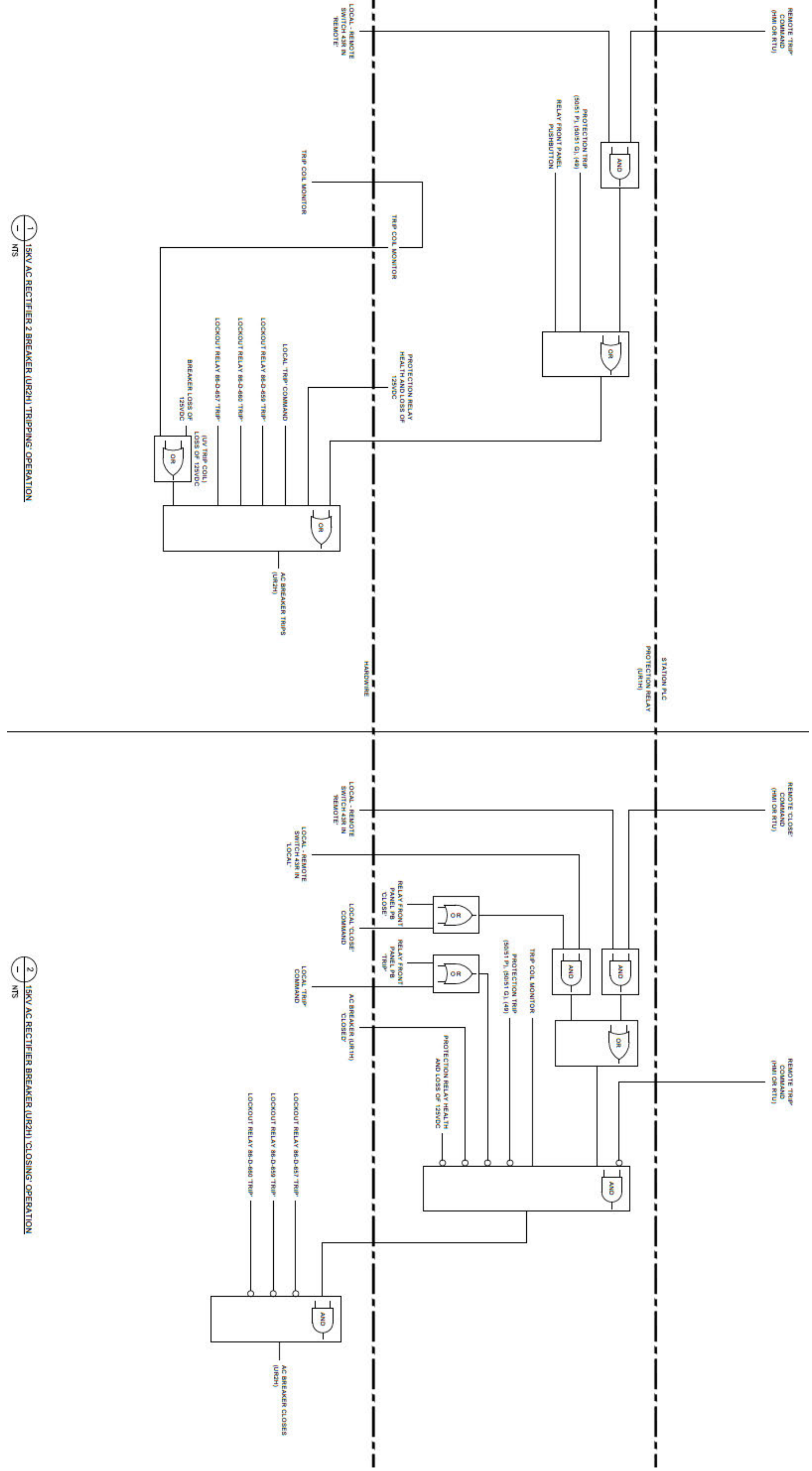


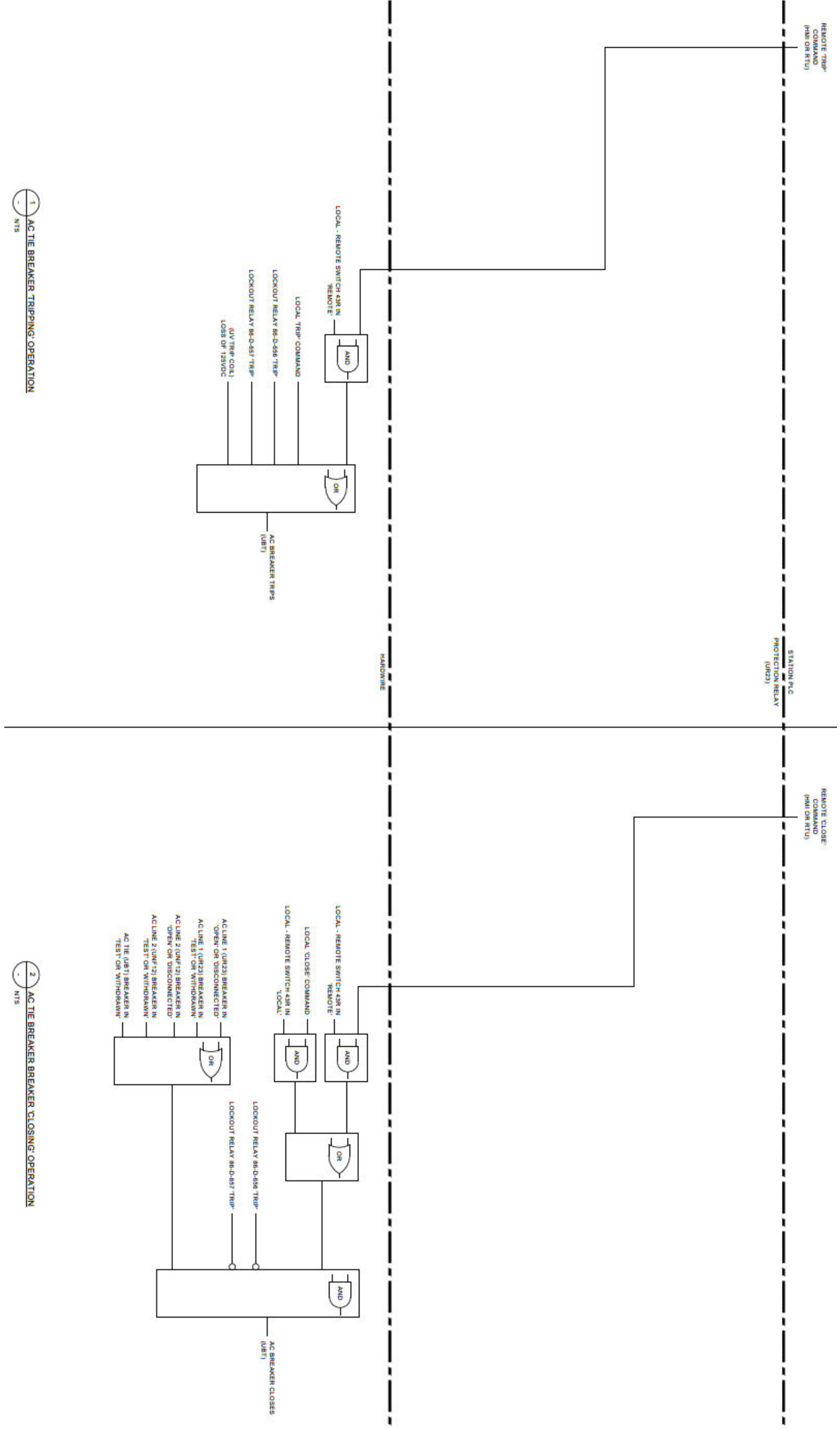
UNIVERSITY TPSS: SAMPLE LOGIC DIAGRAMS


AC SUPPLY BREAKER LINE 2 'TRIP' OPERATION
NTS

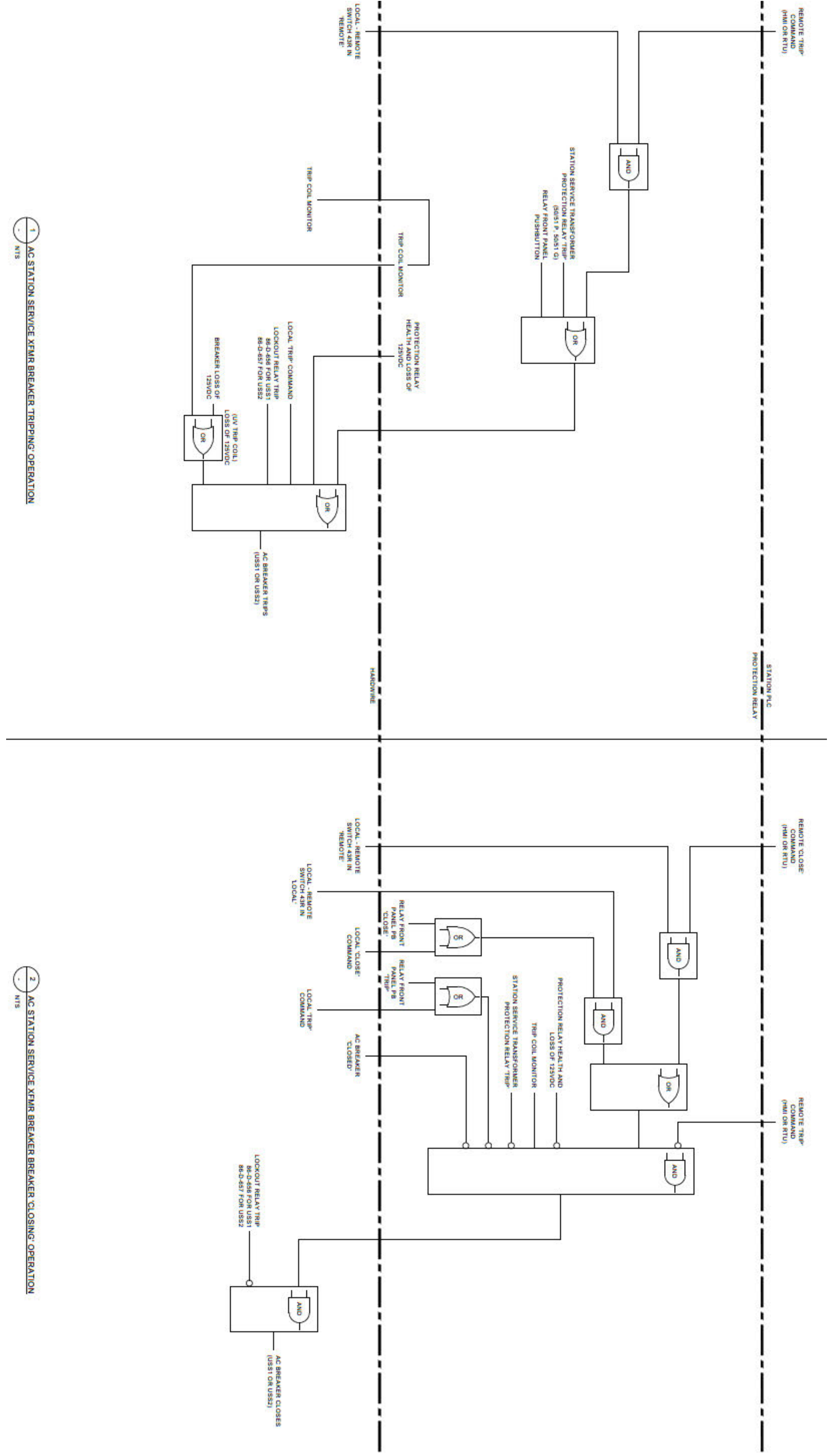

AC SUPPLY BREAKER LINE 2 'CLOSE' SEQUENCE
NTS

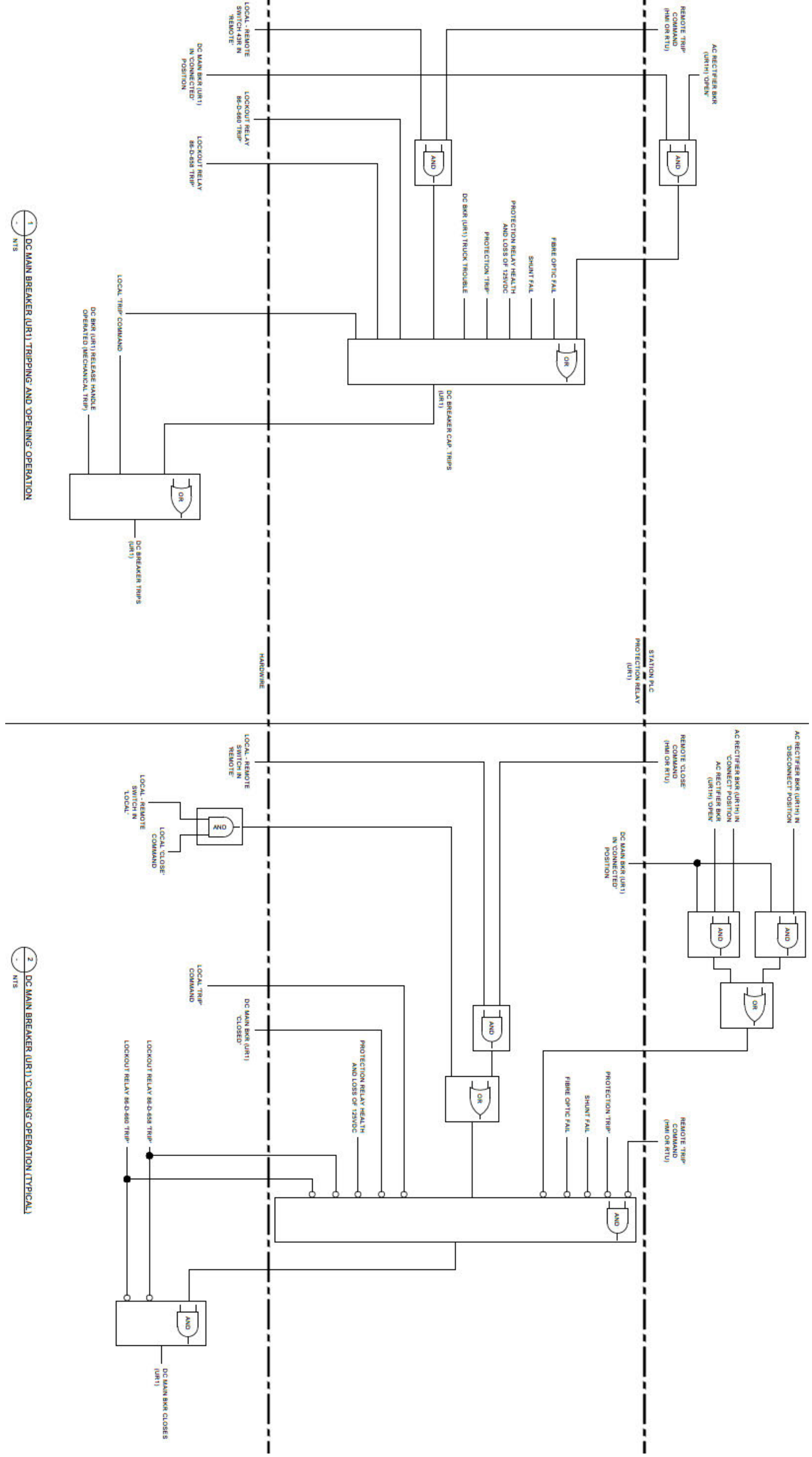

15KV AC RECTIFIER BREAKER (UR1H) 'TRIPPING' OPERATION
15KV AC RECTIFIER BREAKER (UR1H) 'CLOSING' OPERATION

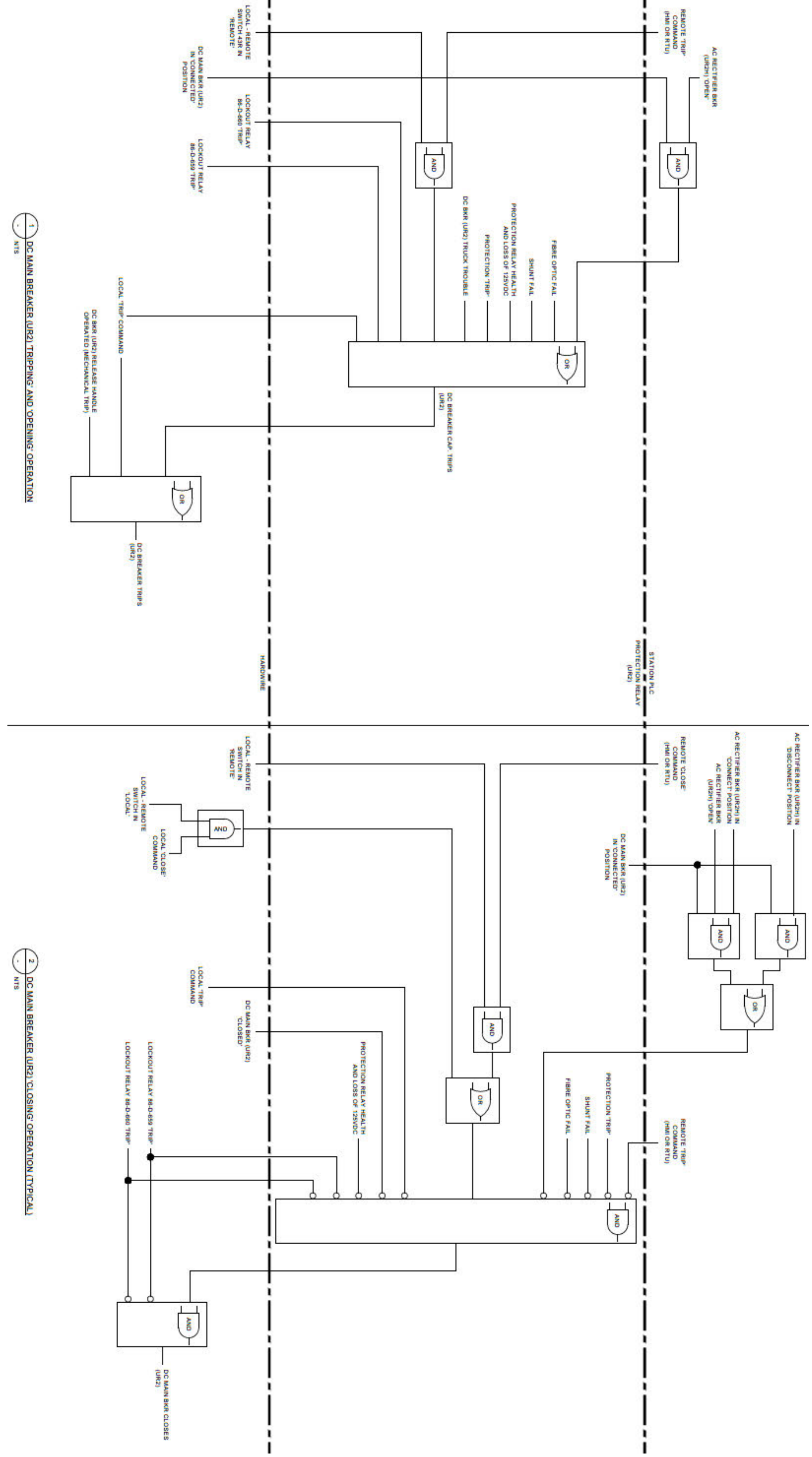

15KV AC RECTIFIER 2 BREAKER (UR2H) 'TRIPPING' OPERATION
NTS
15KV AC RECTIFIER BREAKER (UR2H) 'CLOSING' OPERATION
NTS
HARDWIRE
STATION PLC
PROTECTION RELAY (UR1H)

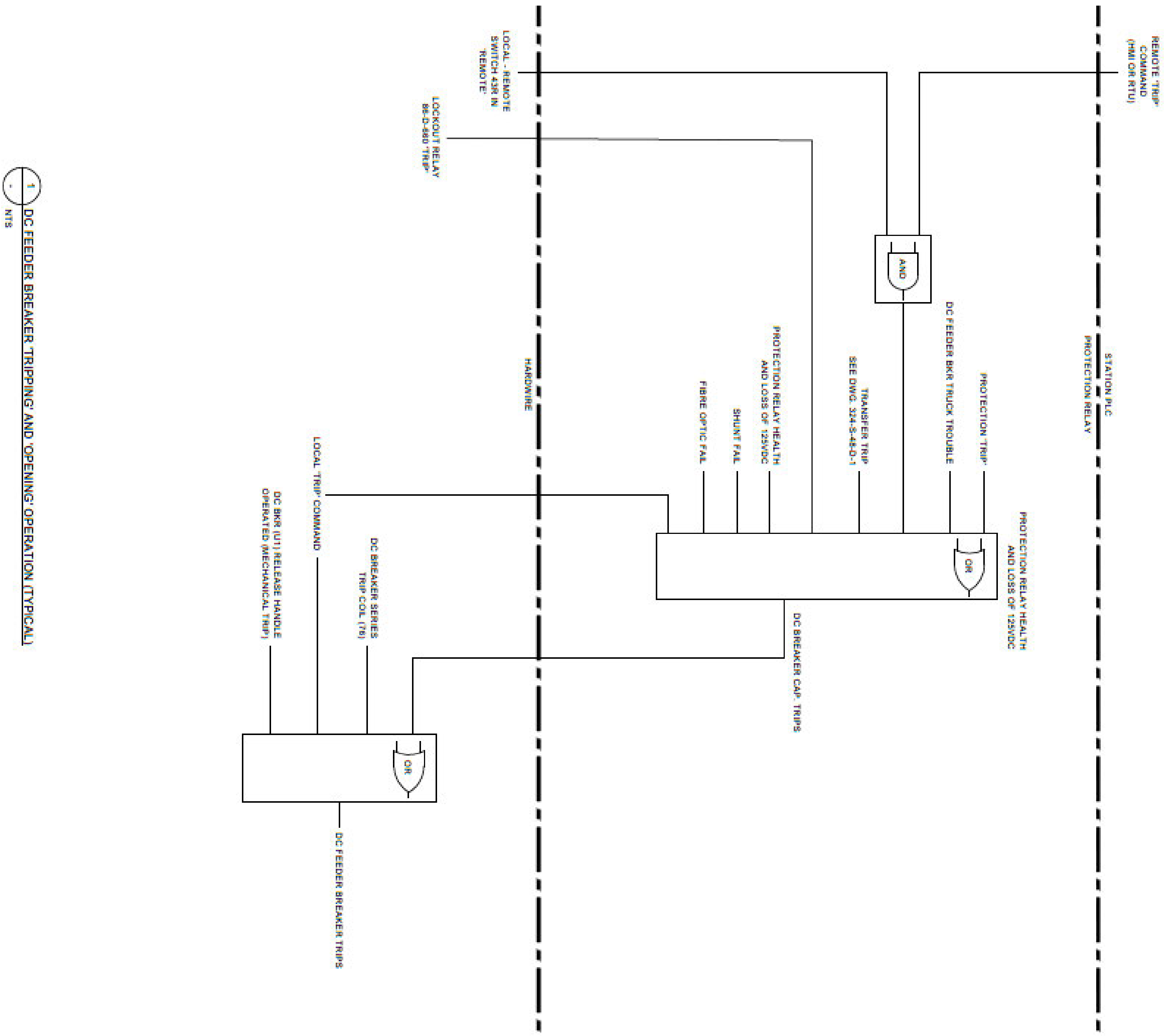


AC TIE BREAKER TRIPPING OPERATION
NTS
LOCAL - REMOTE SWITCH 43R IN 'REMOTE'
LOCAL 'TRIP' COMMAND
LOCKOUT RELAY 86-D-656 'TRIP'
LOCKOUT RELAY 86-D-657 'TRIP'
(UV TRIP COIL) LOSS OF 125VDC
AND
OR
AC BREAKER TRIPS (UBT)
REMOTE 'TRIP' COMMAND (HMI OR RTU)
HARDWIRE
STATION PLC PROTECTION RELAY (UR23)
AC TIE BREAKER BREAKER 'CLOSING' OPERATION
NTS
LOCAL - REMOTE SWITCH 43R IN 'REMOTE'
LOCAL 'CLOSE' COMMAND
LOCAL - REMOTE SWITCH 43R IN 'LOCAL'
AC LINE 1 (UR23) BREAKER IN 'OPEN' OR 'DISCONNECTED'
AC LINE 1 (UR23) BREAKER IN 'TEST' OR 'WITHDRAWN'
AC LINE 2 (UNF12) BREAKER IN 'OPEN' OR 'DISCONNECTED'
AC LINE 2 (UNF12) BREAKER IN 'TEST' OR 'WITHDRAWN'
AC TIE (UBT) BREAKER IN 'TEST' OR 'WITHDRAWN'
LOCKOUT RELAY 86-D-656 'TRIP'
LOCKOUT RELAY 86-D-657 'TRIP'
AC BREAKER CLOSES (UBT)
REMOTE 'CLOSE' COMMAND (HMI OR RTU)

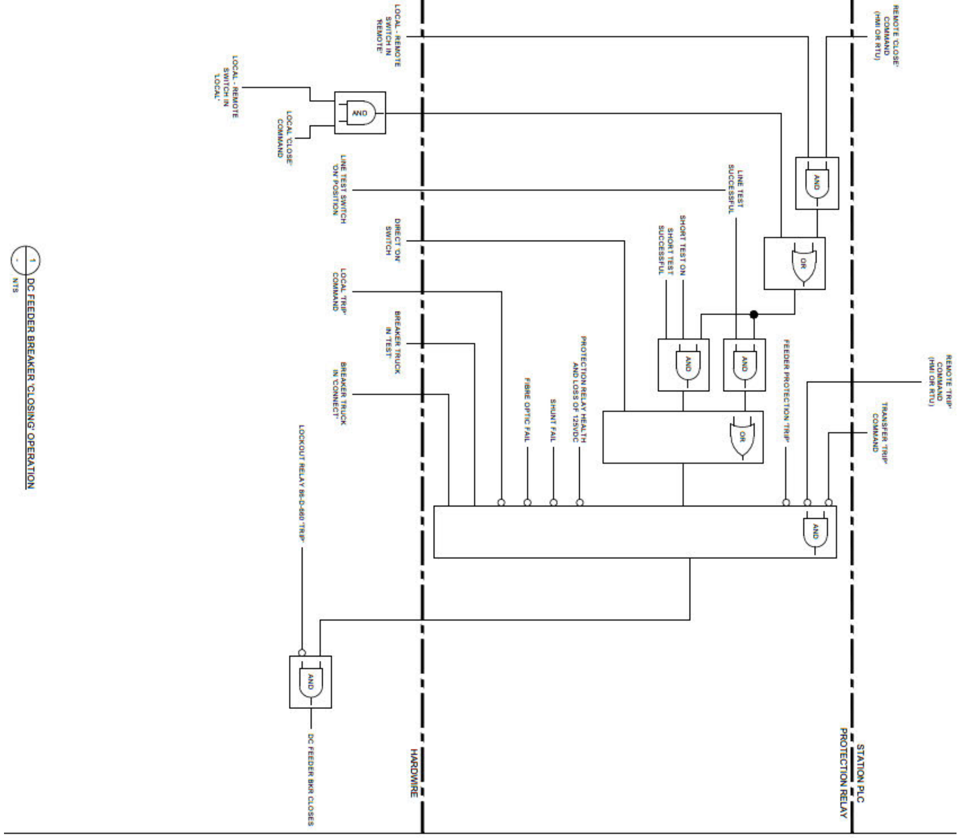

AC STATION SERVICE XFMR BREAKER TRIPPING OPERATION
NTS
AC STATION SERVICE XFMR BREAKER BREAKER 'CLOSING' OPERATION
NTS


DC MAIN BREAKER (UR1) 'TRIPPING' AND 'OPENING' OPERATION
DC MAIN BREAKER (UR1) 'CLOSING' OPERATION (TYPICAL)
HARDWIRE
STATION PLC PROTECTION RELAY (UR1)


DC MAIN BREAKER (UR2) 'TRIPPING' AND 'OPENING' OPERATION
NTS
DC MAIN BREAKER (UR2) 'CLOSING' OPERATION (TYPICAL)
NTS
HARDWIRE
STATION PLC PROTECTION RELAY (UR2)

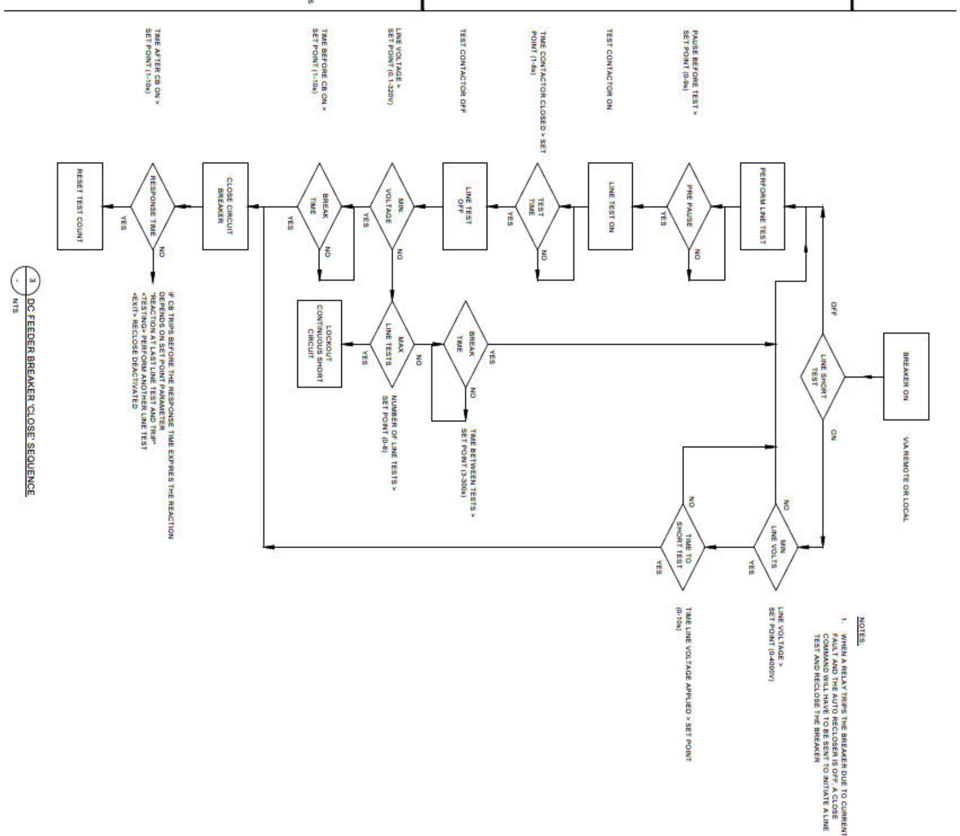


1
-
DC FEEDER BREAKER 'TRIPPING' AND 'OPENING' OPERATION (TYPICAL)
NTS
REMOTE 'TRIP' COMMAND (HMI OR RTU)
LOCAL - REMOTE SWITCH 43R IN 'REMOTE'
LOCKOUT RELAY
AND
STATION PLC
PROTECTION RELAY
HARDWIRE
PROTECTION 'TRIP'
DC FEEDER BKR TRUCK TROUBLE
TRANSFER TRIP
PROTECTION RELAY HEALTH AND LOSS OF 125VDC
SHUNT FAIL
FIBRE OPTIC FAIL
LOCAL 'TRIP' COMMAND
OR
PROTECTION RELAY HEALTH AND LOSS OF 125VDC
DC BREAKER CAP. TRIPS
DC BREAKER SERIES TRIP COIL (76)
DC BKR (U1) RELEASE HANDLE OPERATED (MECHANICAL TRIP)
OR
DC FEEDER BREAKER TRIPS



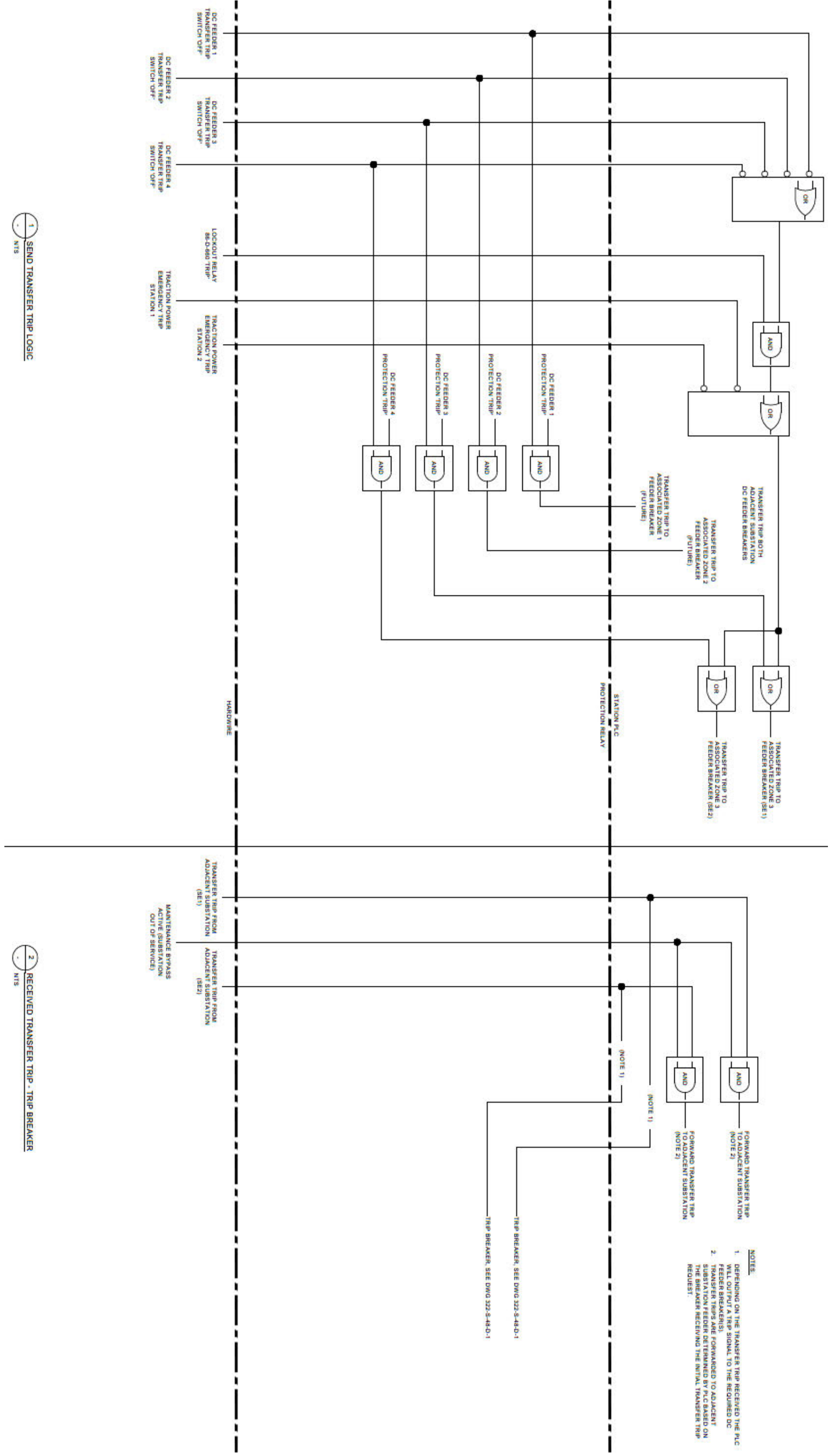
DC FEEDER BREAKER 'CLOSING' OPERATION

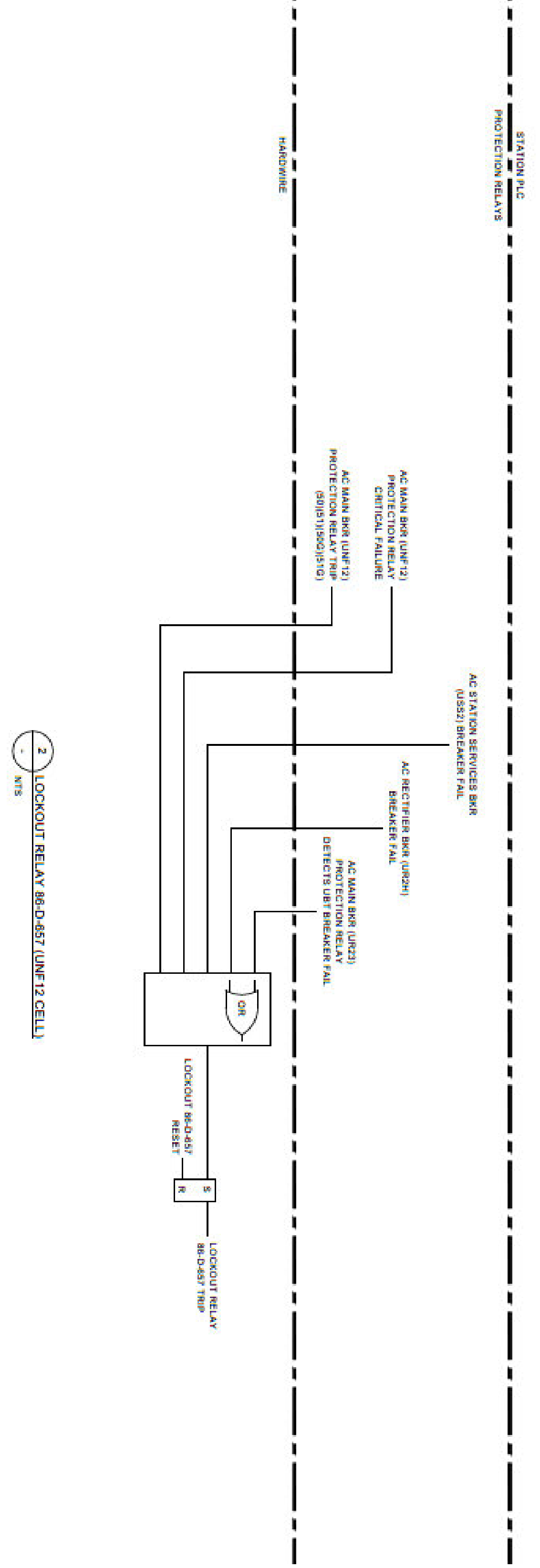
NTS

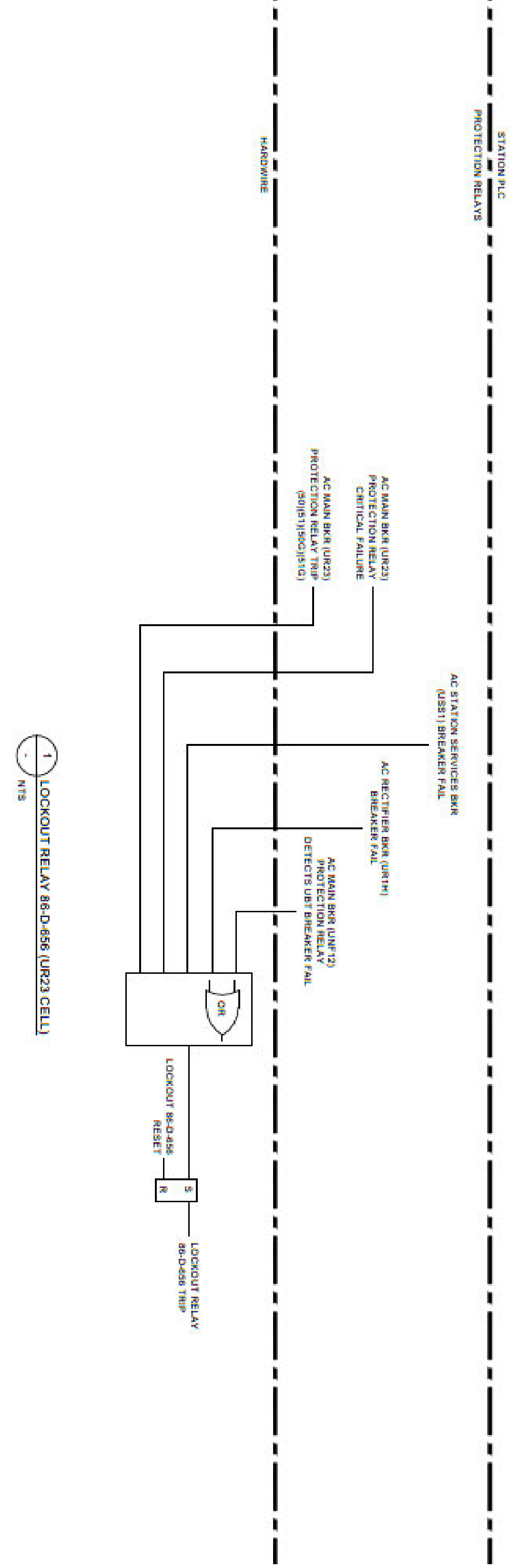


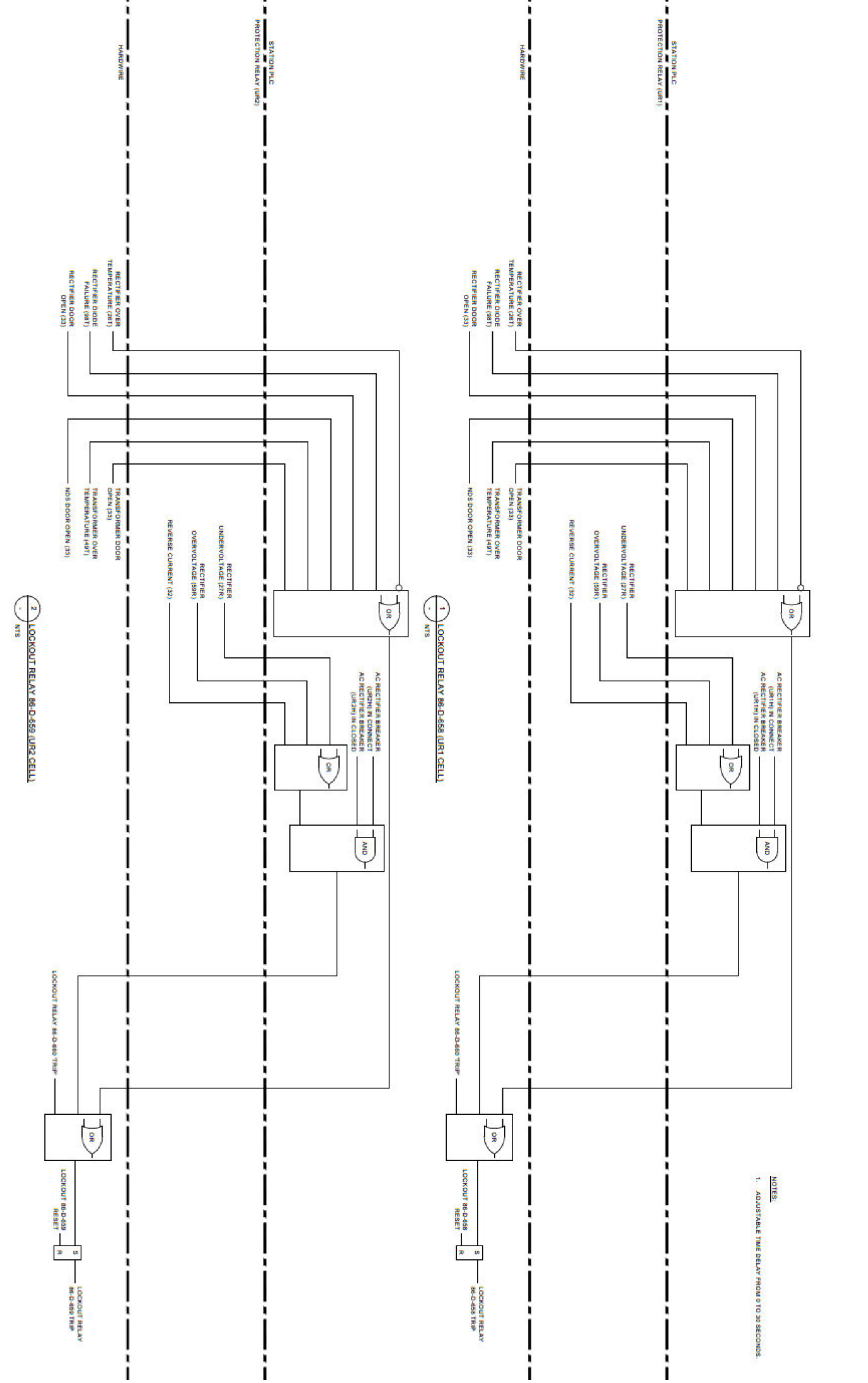
DC FEEDER BREAKER 'CLOSE' SEQUENCE

NTS

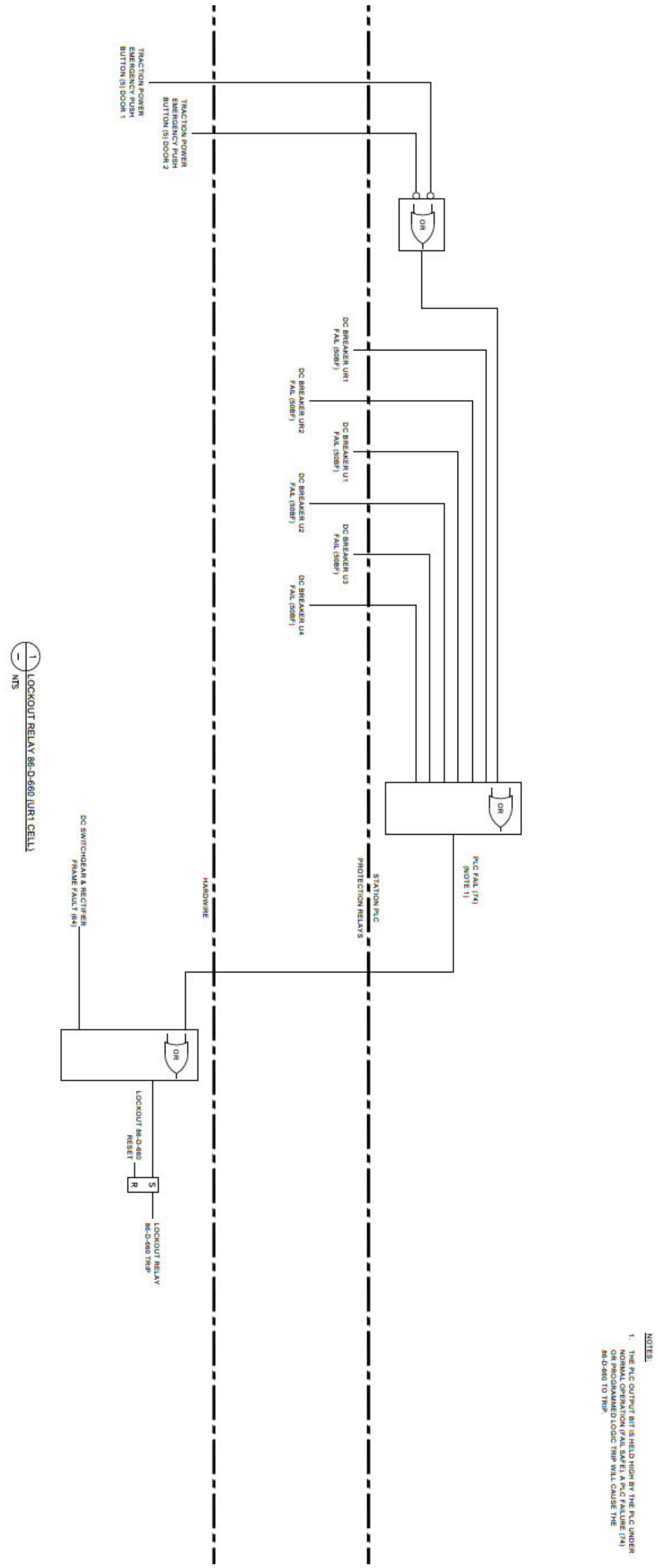

DC FEEDER 1 TRANSFER TRIP SWITCH 'OFF'
DC FEEDER 2 TRANSFER TRIP SWITCH 'OFF'
DC FEEDER 3 TRANSFER TRIP SWITCH 'OFF'
DC FEEDER 4 TRANSFER TRIP SWITCH 'OFF'
LOCKOUT RELAY 86-D-660 'TRIP'
TRACTION POWER EMERGENCY TRIP STATION 1
TRACTION POWER EMERGENCY TRIP STATION 2
OR
AND
TRANSFER TRIP BOTH ADJACENT SUBSTATION DC FEEDER BREAKERS
TRANSFER TRIP TO ASSOCIATED ZONE 3 FEEDER BREAKER (SE1)
TRANSFER TRIP TO ASSOCIATED ZONE 3 FEEDER BREAKER (SE2)
TRANSFER TRIP TO ASSOCIATED ZONE 2 FEEDER BREAKER (FUTURE)
TRANSFER TRIP TO ASSOCIATED ZONE 1 FEEDER BREAKER (FUTURE)
DC FEEDER 1 PROTECTION 'TRIP'
DC FEEDER 2 PROTECTION 'TRIP'
DC FEEDER 3 PROTECTION 'TRIP'
DC FEEDER 4 PROTECTION 'TRIP'
STATION PLC
PROTECTION RELAY
HARDWIRE
1 SEND TRANSFER TRIP LOGIC
NTS
TRANSFER TRIP FROM ADJACENT SUBSTATION (SE1)
MAINTENANCE BYPASS ACTIVE (SUBSTATION OUT OF SERVICE)
TRANSFER TRIP FROM ADJACENT SUBSTATION (SE2)
FORWARD TRANSFER TRIP TO ADJACENT SUBSTATION (NOTE 2)
FORWARD TRANSFER TRIP TO ADJACENT SUBSTATION (NOTE 2)
(NOTE 1)
(NOTE 1)
TRIP BREAKER, SEE DWG 322-S-48-D-1
TRIP BREAKER, SEE DWG 322-S-48-D-1
NOTES:
1. DEPENDING ON THE TRANSFER TRIP RECEIVED THE PLC WILL OUTPUT A TRIP SIGNAL TO THE REQUIRED DC FEEDER BREAKER(S).
2. TRANSFER TRIPS ARE FORWARDED TO ADJACENT SUBSTATION FEEDER DETERMINED BY PLC BASED ON THE BREAKER RECEIVING THE INITIAL TRANSFER TRIP REQUEST.
2 RECEIVED TRANSFER TRIP - TRIP BREAKER
NTS


HARDWIRE
STATION PLC
PROTECTION RELAYS
AC MAIN BKR (UNF12) PROTECTION RELAY CRITICAL FAILURE
AC MAIN BKR (UNF12) PROTECTION RELAY TRIP (50)(51)(50G)(51G)
AC STATION SERVICES BKR (USS2) BREAKER FAIL
AC RECTIFIER BKR (UR2H) BREAKER FAIL
AC MAIN BKR (UR23) PROTECTION RELAY DETECTS UBT BREAKER FAIL
OR
LOCKOUT 86-D-657 RESET
S
R
LOCKOUT RELAY 86-D-657 TRIP
2
-
NTS
LOCKOUT RELAY 86-D-657 (UNF12 CELL)


HARDWIRE
STATION PLC
PROTECTION RELAYS
AC MAIN BKR (UR23) PROTECTION RELAY CRITICAL FAILURE
AC MAIN BKR (UR23) PROTECTION RELAY TRIP (50)(51)(50G)(51G)
AC STATION SERVICES BKR (USS1) BREAKER FAIL
AC RECTIFIER BKR (UR1H) BREAKER FAIL
AC MAIN BKR (UNF12) PROTECTION RELAY DETECTS UBT BREAKER FAIL
OR
LOCKOUT 86-D-656 RESET
S
R
LOCKOUT RELAY 86-D-656 TRIP
1
-
NTS
LOCKOUT RELAY 86-D-656 (UR23 CELL)

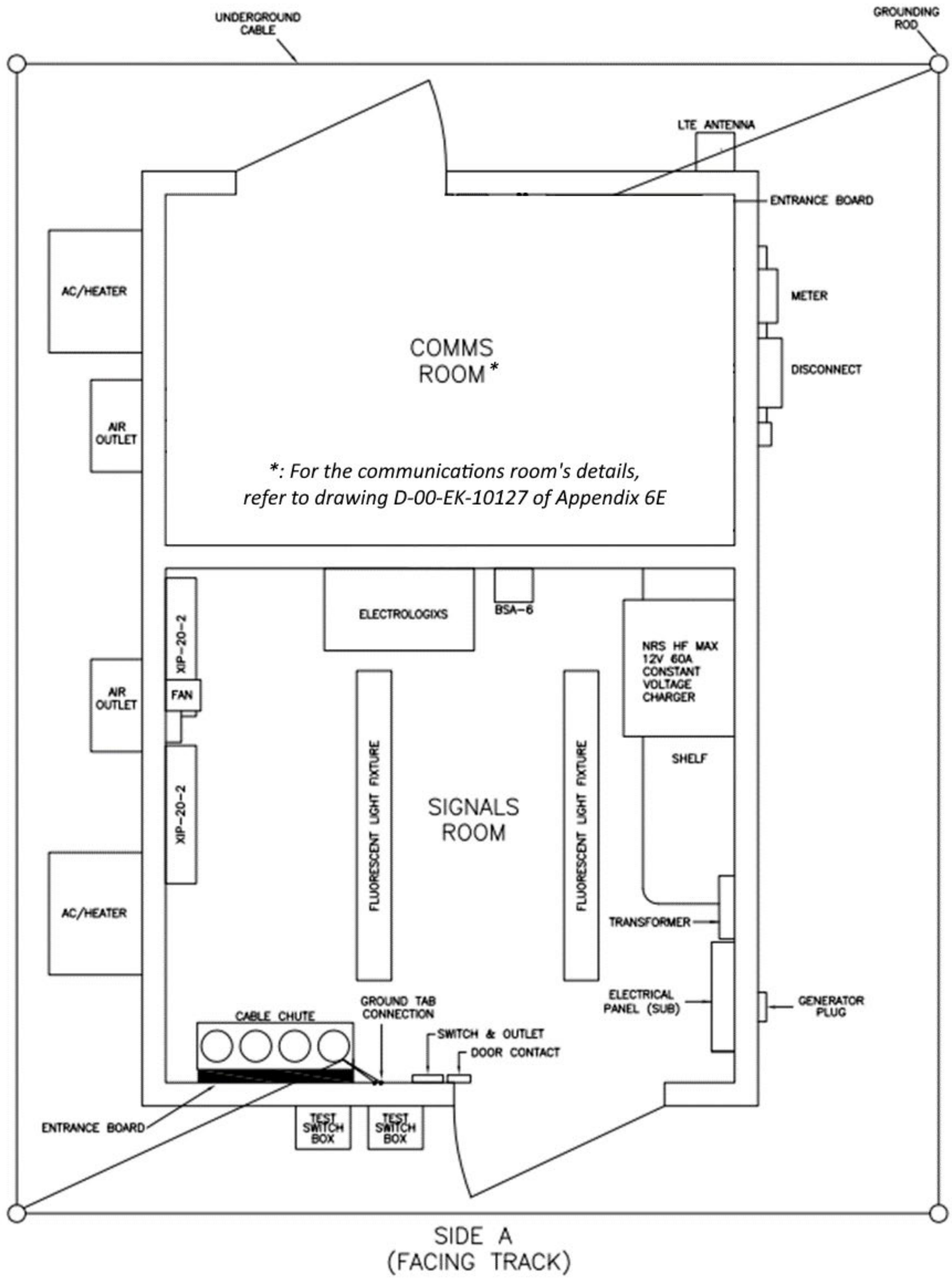


HARDWIRE
STATION PLC
PROTECTION RELAY (UR1)
PROTECTION RELAY (UR2)
RECTIFIER OVER TEMPERATURE (26T)
RECTIFIER DIODE FAILURE (98T)
RECTIFIER DOOR OPEN (33)
TRANSFORMER DOOR OPEN (33)
TRANSFORMER OVER TEMPERATURE (49T)
NDS DOOR OPEN (33)
RECTIFIER UNDERVOLTAGE (27R)
RECTIFIER OVERVOLTAGE (59R)
REVERSE CURRENT (32)
OR
AND
LOCKOUT RELAY 86-D-660 TRIP
LOCKOUT RELAY 86-D-658 (UR1 CELL)
LOCKOUT RELAY 86-D-659 (UR2 CELL)
NTS
NOTES:
1. ADJUSTABLE TIME DELAY FROM 0 TO 30 SECONDS.



TRACTION POWER EMERGENCY PUSH BUTTON (S) DOOR 1
TRACTION POWER EMERGENCY PUSH BUTTON (S) DOOR 2
OR
DC BREAKER UR1 FAIL (50BF)
DC BREAKER UR2 FAIL (50BF)
DC BREAKER U1 FAIL (50BF)
DC BREAKER U2 FAIL (50BF)
DC BREAKER U3 FAIL (50BF)
DC BREAKER U4 FAIL (50BF)
OR
PLC FAIL (74) (NOTE 1)
STATION PLC
PROTECTION RELAYS
HARDWIRE
DC SWITCHGEAR & RECTIFIER FRAME FAULT (64)
OR
LOCKOUT 86-D-660 RESET
S
R
LOCKOUT RELAY 86-D-660 TRIP
1
—
LOCKOUT RELAY 86-D-660 (UR1 CELL)
NTS
NOTES:
1. THE PLC OUTPUT BIT IS HELD HIGH BY THE PLC UNDER NORMAL OPERATION (FAIL SAFE). A PLC FAILURE (74) OR PROGRAMMED LOGIC TRIP WILL CAUSE THE 86-D-660 TO TRIP.

APPENDIX 6D DOUBLE ROOM SIGNALS BUNGALOWS LAYOUT



APPENDIX 6E COMMUNICATIONS DESIGN PRELIMINARY REPORT

APPENDIX 6F DEMARCATION POINTS CHECKLIST

Checklist for the City to start ETS Network and Corporate IT Network integration

The following requirements are the minimum work that must be completed by the Design-Builder prior to the City beginning their integration work.

No.#	Items	Location	Required Percentage Complete
1	Complete the civil work for the entire UC, OMF communications room, and double room bungalows	UCs, double room bungalows, and OMF comms rooms for the entire CLSE Project	100%
2	Complete the mechanical work inside the communications, signals, and TPSS rooms, including PICOs and SAT	UCs and OMF comms rooms for the entire CLSE Project	100%
3	Complete the grounding system work for the communications, signals, and TPSS rooms	UCs and OMF comms rooms for the entire CLSE Project	100%
4	Complete the communications power system work, with successful testing and commissioning	UCs and OMF comms rooms for the entire CLSE Project	100%
5	Complete the installation of the demarcation points	UCs and OMF comms rooms for the entire CLSE Project	100%
6	Complete the termination of the incoming cables and wires inside the demarcation points	Twin Brooks, Anthony Henday, Llew Lawrence, Heritage Valley, and the double rooms bungalows	100%
7	Complete the labeling for all cables and wires from both sides up to the demarcation points	Twin Brooks, Anthony Henday, Llew Lawrence, Heritage Valley, and the double rooms bungalows	100%
8	Complete and submit the red-line version of the cable schedule documentation for the demarcation points	Twin Brooks, Anthony Henday, Llew Lawrence, Heritage Valley, and the double rooms bungalows	100%
9	Ensure easy and exclusive access to the communications rooms with proper security	UCs and OMF comms rooms for the entire CLSE Project	100%
10	Ensure all the safety life systems are working inside the rooms	UCs and OMF comms rooms for the entire CLSE Project	100%